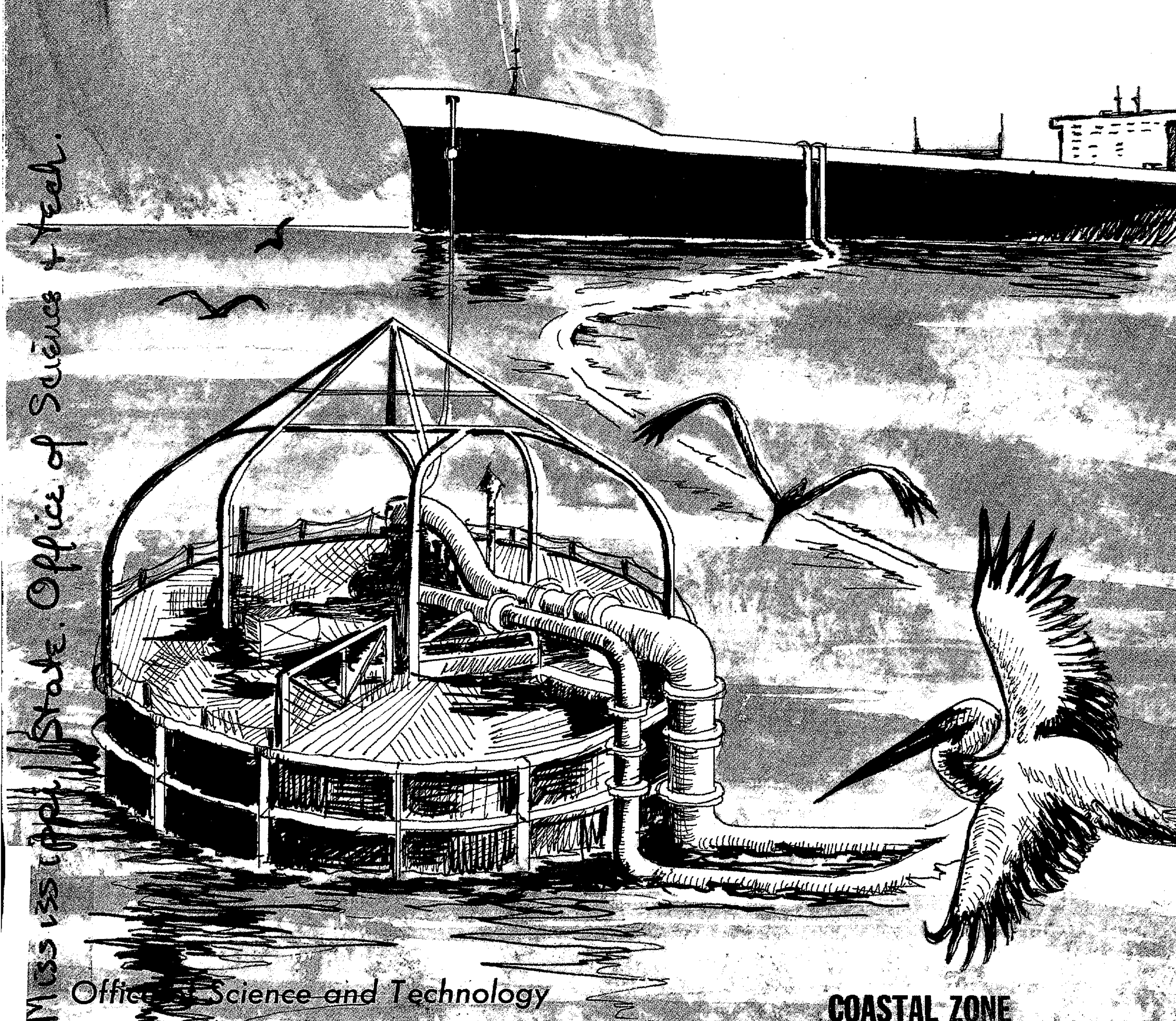
MISSISSIPPI SUPERPORT STUDY

Environmental Assessment

Charles K. Eleuterius



Miss State. Office of Science + Tech.

Office of Science and Technology
Dr. T. P. Bankston, Director

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MISSISSIPPI SUPERPORT STUDY ENVIRONMENTAL ASSESSMENT

Prepared by

Charles K. Eleuterius

For

OFFICE OF SCIENCE AND TECHNOLOGY
OFFICE OF THE GOVERNOR
STATE OF MISSISSIPPI
DR. T. P. BANKSTON, DIRECTOR

ACKNOWLEDGMENTS

In the preparation of such a comprehensive report, it was necessary to depend on the work of many other researchers. The style adopted for this report precluded the acknowledgment of their contributions in the text; however, the sources referenced are listed in the Sources Referenced section of the report. These individuals and their efforts have made this assessment possible.

I wish to thank Mr. Paul Poole for his very capable handling of the computer programming required.

Mrs. Joyce Randall Edwards worked tirelessly in the rewriting, typing, proofing, and general preparation of the report. Her contributions are deeply appreciated.

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INTRODUCTION

By the year 1985, the energy demands of the United States are expected to reach the equivalent of 60-million barrels of petroleum per day. Domestic sources of energy including petroleum, natural gas, nuclear power, coal, and hydroelectric power are projected to meet only three-fourths of the national requirement. In order to meet the 1985 energy requirement, the United States will need to import 52 percent of its crude oil requirements to supplement production from its dwindling domestic energy sources.

Supertankers of 100,000 to 300,000 DWT (dead weight tonnage) must be employed to economically and expediently transport the large quantities of required crude. The utilization of the deep-draft supertankers requires an approach channel and port depth of 120 feet. Presently, no ports on the Gulf of Mexico or on the Atlantic seaboard can accommodate such vessels. The depth constraint and the economically impractical and environmentally undesirable massive dredging required to achieve and maintain the required depth make the employment of single point mooring systems (monobuoys) a feasible alternative with several definite advantages over conventional ports.

The purpose of this report is to bring into focus the various natural forces and factors that should be addressed in the judicious planning for the construction and operation of a Superport monobuoy to insure not only the successful operation of the port but also the continued integrity of the marine environment. No good purpose would be served, indeed, in destroying the vitally important marine environment and thus the marine dependent industries of commercial fisheries, tourism, and their ancillary services in the pursuit of supplying another essential resource. A combination of information gathered from both published and unpublished sources and data gathered on hydrographic cruises in support of this effort make up the basis of this assessment. The information from various sources was synthesized and integrated to depict a comprehensive picture of the environmental factors that must be considered.

Because the environmental forces and factors that must be considered do not recognize any imaginary boundary that might be placed about a particular area of interest, it is necessary to study the larger dynamic system, the Gulf of Mexico; and with this perspective, concentrate upon the specific area of interest. In a closer inspection of the specific site location, approximately 25 miles south of Pascagoula, Mississippi, a more detailed discussion of the physical, chemical, and biological factors will be instituted.

ENVIRONMENTAL SETTING

A relatively shallow, oceanic-type basin, the Gulf of Mexico has a surface area of 1.602 million km^2 (0.619 million square statute miles) and a maximum depth of approximately 3,788 meters (2,080 fathoms). Together, the Gulf of Mexico and the Caribbean Sea are termed the "American Mediterranean." The subtropical climate resulting from the presence of the "Bermuda High" and the heat capacity of the oceanic Gulf waters provides ideal conditions for year-around commerce on the contiguous land areas.

The site proposed for the employment of a Superport monobuoy is situated in the Gulf of Mexico (Figure 1, Figure 2) on the continental shelf northeast of the Mississippi River Delta and north-northwest of the Yucatan Straits. The proposed site is approximately 25 miles south of the port city of Pascagoula, Mississippi, which in 1973 with a gross tonnage of 14,035,325, ranked twentieth in U. S. ports. Within a radius of 30 miles of the site are five major waterways: Mississippi River, Tennessee-Tombigbee, Intracoastal, Pat Harrison, and Pearl River.

Figure 2 depicts the proposed site of the monobouy (single point mooring system), the pumping platform approximately four miles to the north, and the route of the pipeline into Mississippi Sound through Horn Island Pass paralleling the existing ship channel to the Bayou Casotte Industrial Park. Both the monobuoy and pumping platform sites are removed from the shipping lanes and any existing drilling sites or lease areas.

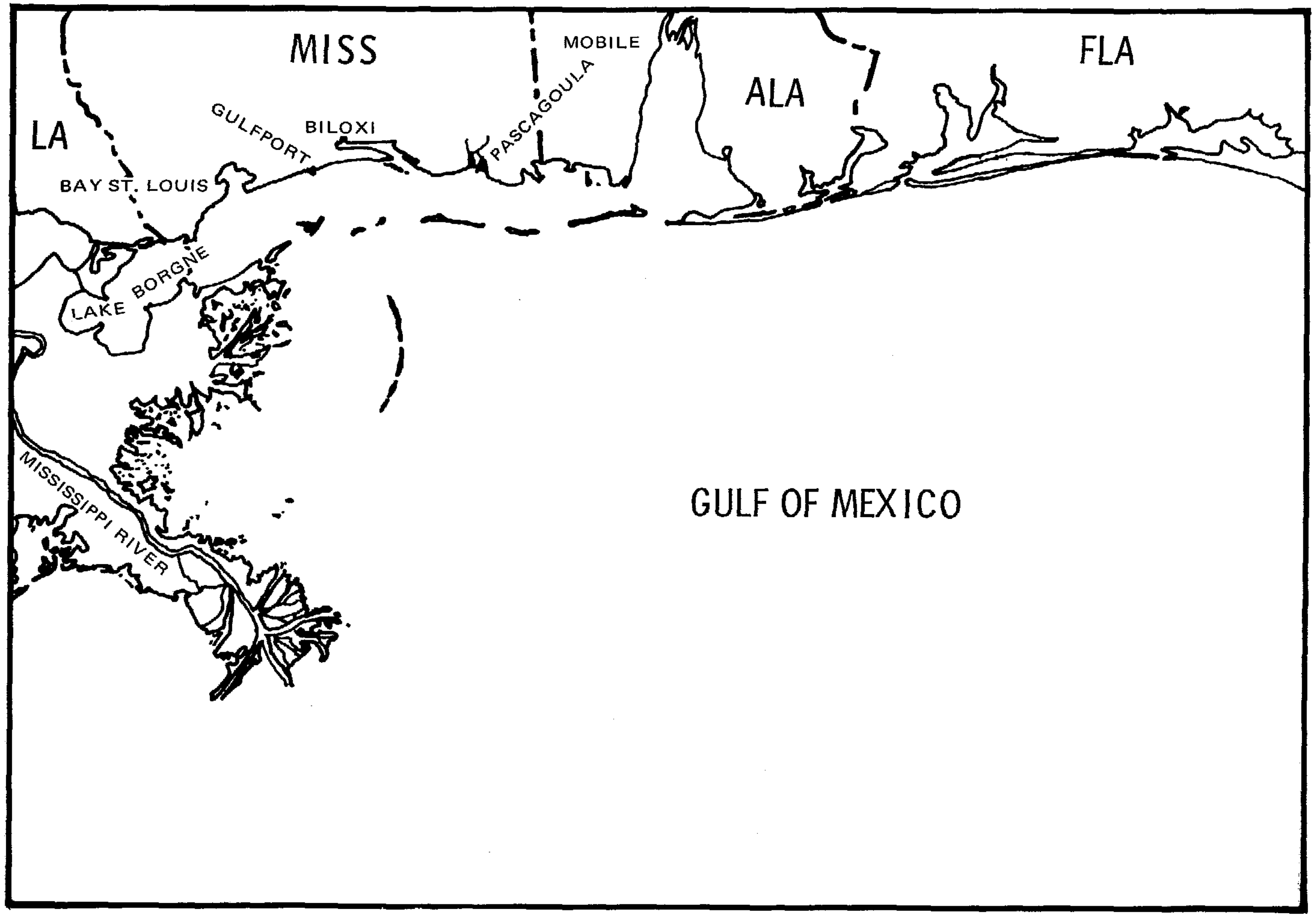


FIGURE 1. LOCATION MAP, AREA OF PROPOSED SUPERPORT.

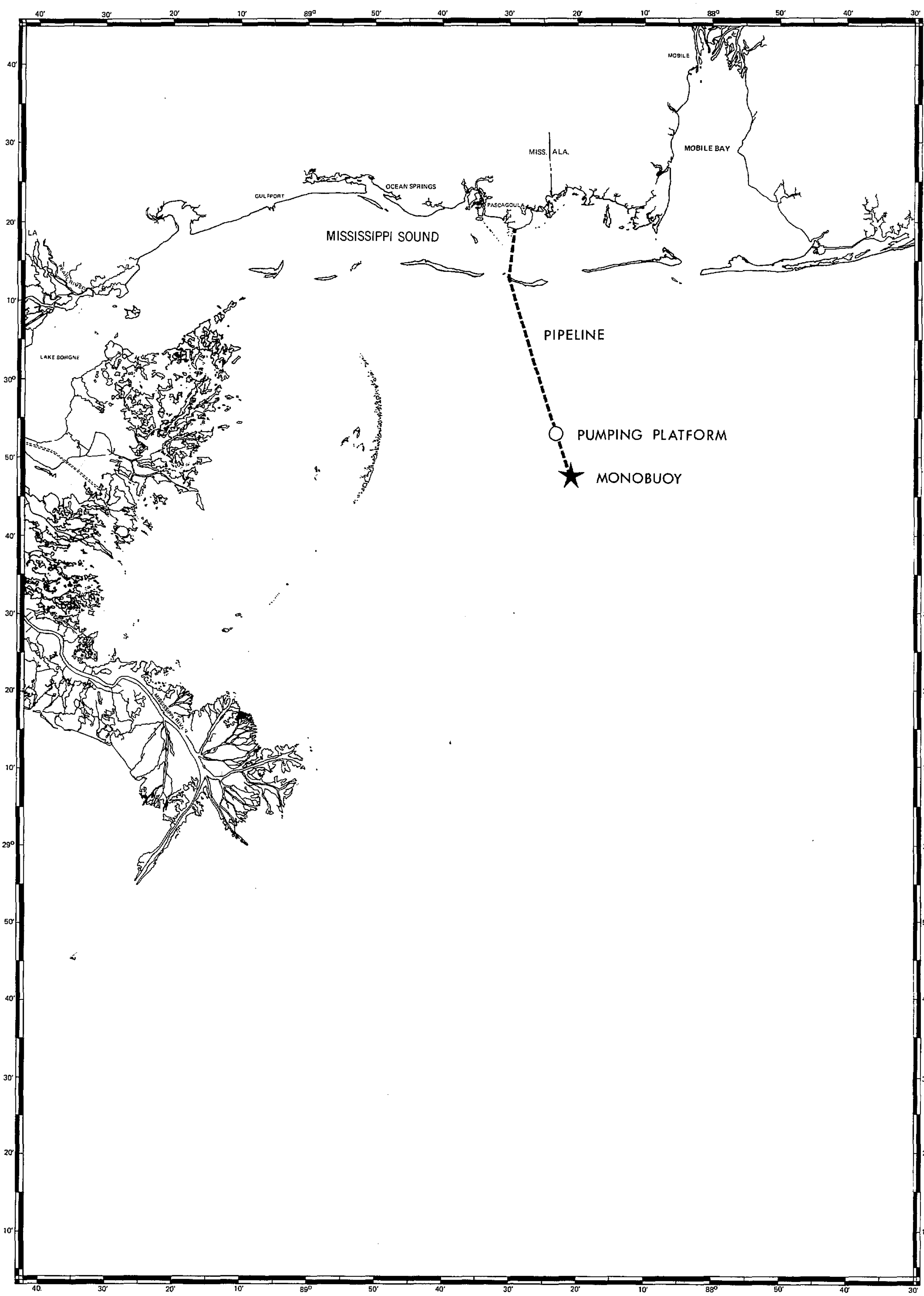


FIGURE 2. PROPOSED SITE OF SUPERPORT.

Geology

Physiography of Gulf of Mexico

The bathymetry of the Gulf of Mexico (Figure 3) is basin-like with the deepest portion of the basin (Sigsbee Abyssal Plain) located in the southwestern section. Compared to average Gulf depths, the entrances to the Gulf are relatively shallow; the Yucatan Straits having a maximum depth of approximately 2,103 meters (6,900 feet); and Florida Straits having a maximum depth of approximately 997 meters (3,270 feet). The widest continental shelf areas lie off the coasts of east Texas; Louisiana, west of the Mississippi Delta; and Florida, south of the panhandle. The intrusion of the isobaths in a northeast direction south of Mississippi and Alabama constitutes the submarine DeSoto Canyon. The relatively narrow shelf area in this section of the Gulf provides access to waters in excess of 183 meters (600 feet) within 52 kilometers (32 miles) of the proposed Superport site.

The Gulf of Mexico consists of seven distinct geological provinces (Figure 4): (1) the South Florida Platform, a carbonate bank, depicts a previous basin located on the west Florida continental shelf; (2) the Yucatan Platform and Campeche Bank appear to be an extension of the carbonate platform of south Florida that was bisected possibly by erosion; (3) the Isthmian Embayment possesses thick Tertiary sediments, and vertical salt movement is the major geological process of the province; (4) the continental shelf and slope of east Mexico consist of a bottom relief of folds parallel to the shoreline and caused by the extrusion of salt from beneath the continental land mass; (5) the Gulf Basin consists of an oceanic crust and a thick overlying layer of sediment; (6) the northeastern Gulf continental shelf and slope are subsiding carbonate banks; (7) the main feature of the northwestern Gulf is the Gulf Coast Geosyncline which extends into the Gulf as far as the Sigsbee Scarp.

The sediments comprising the continental shelf and slope of south Florida become thicker and increasingly carbonaceous toward their southward extent. The sediment type and depositional history imply that the area was once a closed basin whose barriers were drowned upon subsidence of the carbonate platform.

The Campeche Bank is a large, plateau-like carbonate bank bounded by the Yucatan Straits on the east and the Tabasco-Campeche Basin on the west. The western boundary of the Campeche Bank expresses a gradual transition from carbonate to primarily terrigionous material.

A sequence of mountain building, down faulting, and salt depositions resulted in the geological evolution of the Bay of Campeche and the Isthmian Embayment. The seaward topography of the Bay is comprised of a series of long ridges parallel to the perimeter of the basin; this topographic feature purportedly being caused by the extrusion of salt from beneath the continental land mass upward vertically through the overlying sediments.

The East Mexico Continental Shelf and Slope encompass the whole western border of the Gulf of Mexico south of the Rio Grande River. A series of folds parellel to the shoreline, characterizing the topography of this area, extends seaward with the outer edge buried beneath the sediments of the shelf and upper continental slope. The crest-to-crest distance of the folds is approximately 5.5 miles with a vertical distance measured from trough-to-crest of approximately 457.2 meters (1,500 feet). The series of folds in the area has served to pond sediments being transported seaward from Mexico. When sediment deposition into the interior of the impoundment, formed by the first fold and the shoreline, exceeds the maximum elevation of the fold, the sediment spills over into the next more seaward impoundment. The entire series of ridges in the area is the result of salt being squeezed from under the continental land mass.

The Mississippi Cone, the continental rise, and the Sigsbee Abyssal Plain comprise the three divisions of the Gulf's central basin. The Mississippi Cone which extends toward the southeast from the Mississippi Trough consists of thick sediments with a seaward gradation finally mixing with the sediments of the abyssal basin. The continental rise is primarily a build-up of sediments transported south. The absence of such a rise adjoining the Campeche Bank and Florida Platform, which display instead steep escarpments, is due to the lack of sedimentary material being transported into the basin from the east or south.

With a slope of 1:8000, the Sigsbee Abyssal Plain is frequently termed the flatest piece of the Earth's surface. The thick, level sedimentary layers are the result of the occurrence of frequent turbidity currents originating at the edge of the continental shelf along a stretch from the Mississippi Delta westward to the present Atchafalaya River, the old route of the Mississippi River.

Turbidity currents are caused by a failing of the sediment structure built at the edge of the shelf by deposition of silt and sands carried into the area by the river outflow. Initiation of the "failing" or "slumping" can be caused by one or a combination of several factors: continuous sediment build-up exceeding the load bearing capacity; storm surges accompanying hurricanes or tropical storms; local or remote earthquakes; and even normal tidal action when the load bearing weight becomes critical. Turbidity currents, the result of "land slides," contain tremendous amounts of silt, sand, clay, and other material in suspension and traveling at speeds (computed from measurable occurrences) in excess of 80 kilometers per hour (50 miles per hour).

Protruding through the otherwise level sedimentary bottom of the Sigsbee Abyssal Plain are knolls and domes which have definitely been shown to be salt diapiric structures.

The continental shelf, delta, and estuarine bathymetry are depicted in Figure 5 where the sea-bottom topography is deliberately exaggerated in the vertical by a factor of 20 in order to emphasize the pertinent geological features. In the right hand corner of the picture, which would be southeast of the proposed site, the DeSoto Canyon is depicted extending northeast toward Pensacola, Florida. The rather abrupt, cliff-like feature in the central portion of the picture and paralleling the bottom edge of the picture is the continental slope frequented by a significant number of commercially valuable but unexploited marine species such as large isopods, clawless lobsters, and the famous "Royal Red" shrimp.

The bird foot type delta of the Mississippi River depicts the multitude of passages that have passed through a sequence of being active, inactive, and then finally abandoned. The platform-like structure comprising the delta proper is the result of continuous "upbuilding" and "outbuilding" from sediment deposition. The outer edge of the steep slope along the outer deltaic platform is unstable due to the unconsolidated nature of the sediments; deposited sediments exceeding the critical "overbearing" weight limit; and continuing decomposition of organic-detritus deposited throughout the platform. This area, subject to frequent hurricanes and associated storm surges, is particularly vulnerable to slumping and resulting turbidity currents.

The salt diapirs appear as conically shaped hills throughout the area covered in the illustration. These diapiric structures correlate highly with the presence of oil bearing subterranean geological structures. It appears from present seismic reflection data that the DeSoto Canyon is the eastern extent of these salt formations indicating a thinning of the salt layer.

The broad, scoured trough and surrounding area occupying the central portion of the illustration are predominately covered by mud-sand, well-consolidated sediments. The deepest portion of the upper reaches of this trough is the proposed site of the monobuoy; this location being centrally located and accessible to major water routes to the interior (Mississippi River, Tennessee-Tombigbee, Pearl River, and Pat Harrison Waterway) and along the coastal perimeter (Intracoastal Waterway).

On the mainland side of the barrier islands lie extensive, valuable estuarine areas. The bays and sounds serve as nursery areas for the young of many economically important marine species. At the top-center of the illustration behind the series of barrier islands lies Mississippi Sound. It is proposed that the path of the pipeline from the monobuoy to the mainland transverse Mississippi Sound along a route west of Petit Bois Island and parallel to the existing ship channel reaching the shoreline at the Bayou Casotte Industrial Park.

The following discussion deals with the geology and physiology of Mississippi Sound and coastal zone in general and specifically with the eastern portion of Mississippi Sound from Bayou La Batre, Alabama, to Pascagoula, Mississippi.

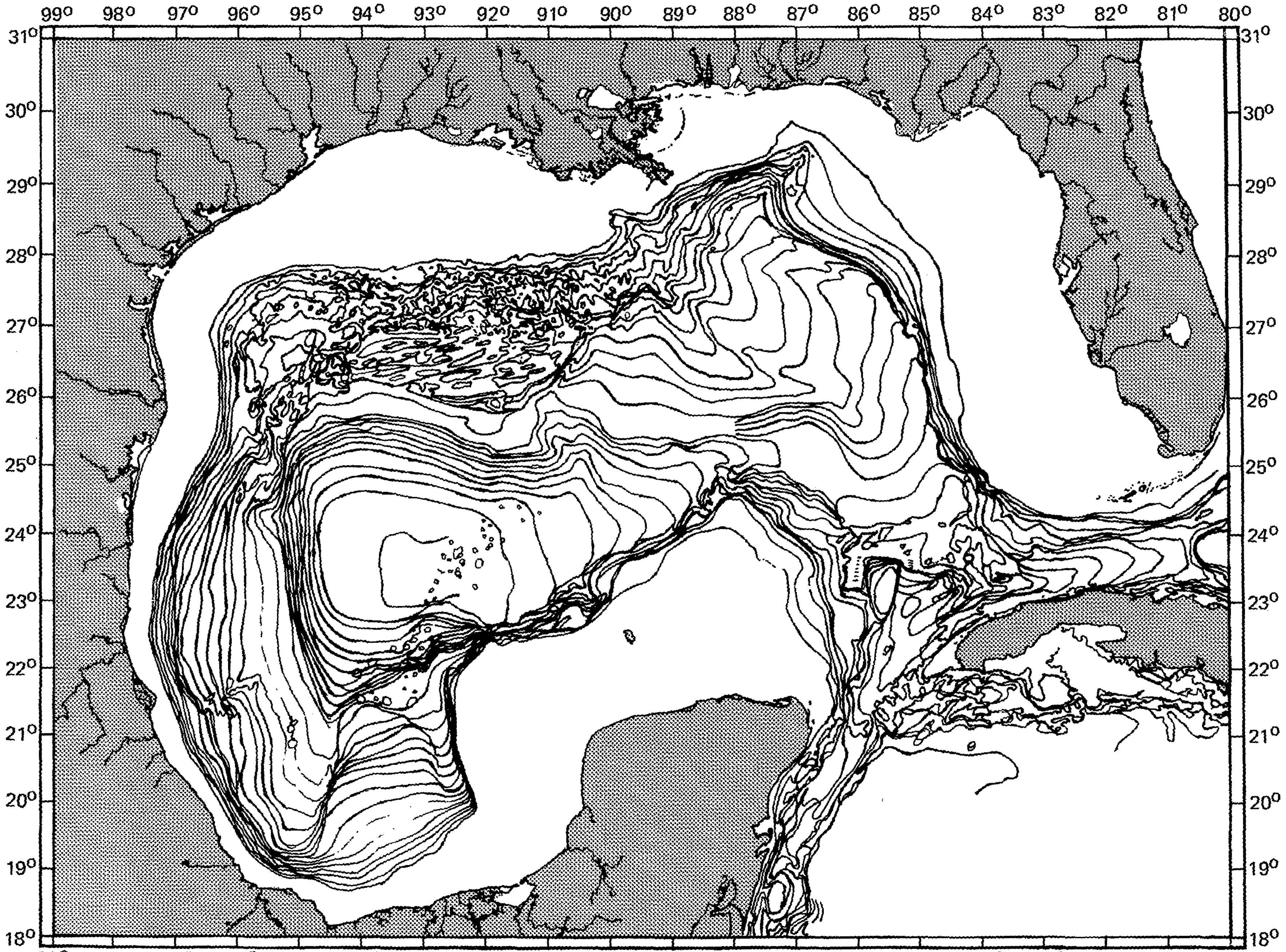


FIGURE 3. BATHYMETRY OF GULF OF MEXICO.

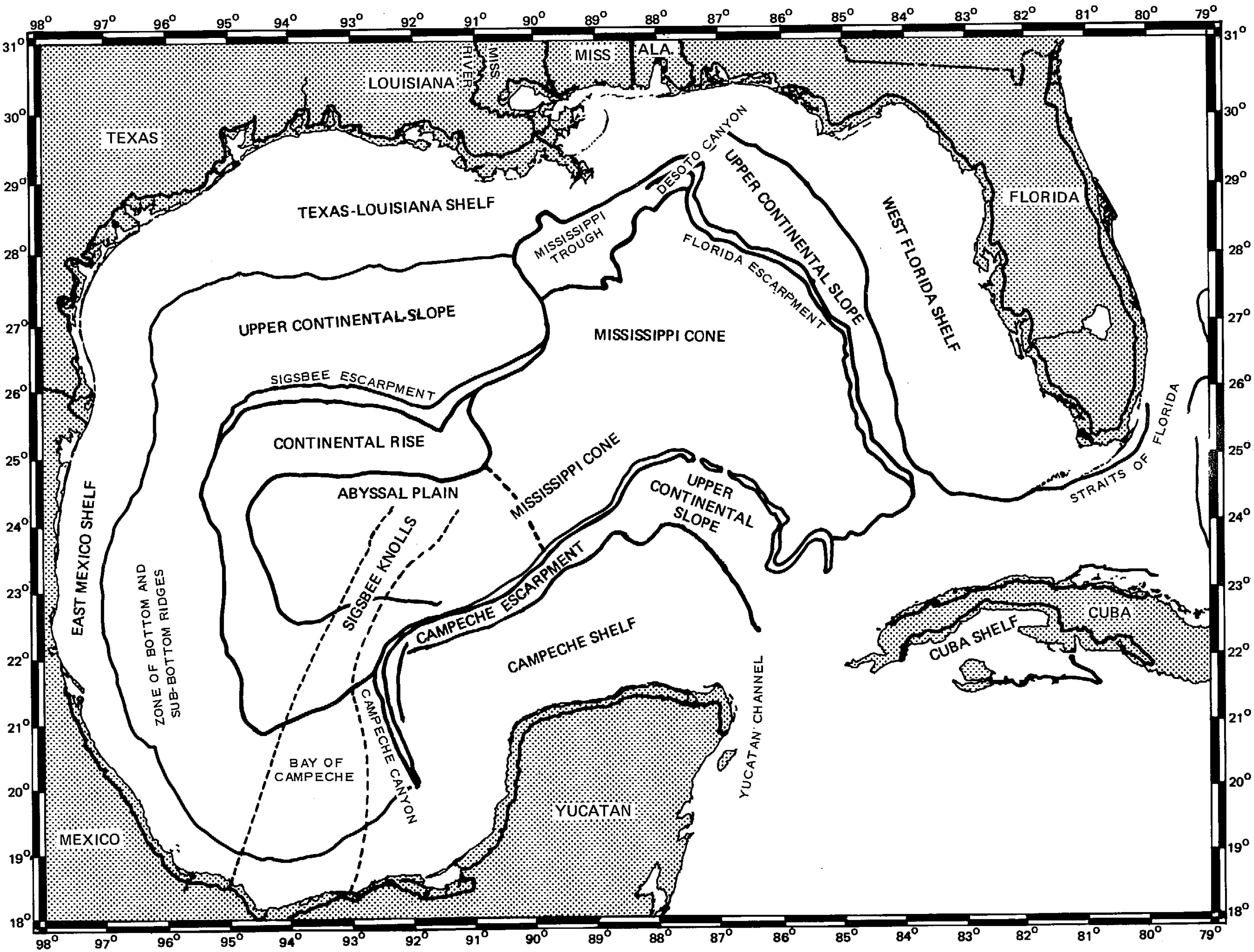


FIGURE 4. PHYSIOGRAPHIC PROVINCES OF GULF OF MEXICO.

FIGURE 5. CONCEPTUAL PRESENTATION OF SEA FLOOR RELIEF.

Geological History of Area

The oldest surface desposits in the study area date back to Mid-Pliocene times when a coalescing apron of fluvial-deltaic deposits covered the entire region and laid down the Citronelle Formation. Subsequent regional uplift and erosion resulted in the elevation and partial removal of these deposits during Pleistocene times. Earlier Pleistocene fluvial sediments were deposited later immediately north of the study area and probably also under the present Mississippi Sound. Erosion, following this sedimentation period, again removed much of the earlier Pleistocene sediments.

Toward the end of the Pleistocene Epoch, marine transgression covered up the region of the present Mississippi Sound and the southernmost fringe of the mainland coast. The nearshore, occasionally lagoonal Biloxi Formation formed during this marine influx. At the same time, fluvial sedimentation was responsible for the deposition of the Prairie (Pamlico equivalent) Formation along the ancient seashores. Beach-dune barrier ridges formed east and west of the subject area (Gulfport Formation) on the shore. Round Island, southwest of Pascagoula in the Mississippi Sound, appears to be one remnant of the Late Pleistocene coastal barriers.

Withdrawal of the Late Pleistocene sea was followed by continued fluvial deposition as the seashore retreated southward (Prairie Formation) and eroded. The coastal streams cut their valleys into the Prairie and the underlying formations; and at the peak of the last glacial period (Wisconsin), the seashore was located probably 90-120 miles south of the present shoreline.

With the return of the sea, toward the very end of the Pleistocene and during early Holocene times (16,000 - 4,000 years ago), the excavated fluvial valleys filled first with freshwater sediment and later with brackish marine deposits. Marshes and swamps developed behind the shores as waters were dammed back. In addition to the Pascagoula River, which occupied about the same position it does today, the Escatawpa River was the second major river in the area, but followed a course different from its present-day course. A complex system of meanders near Orange Grove and Pecan and south of these locations indicates that the Escatawpa River flowed due south-southeast and emptied into Grand Bay. Bayous Cumbest and Heron are remnants of the main Escatawpa River channels which built a sizable delta into Grand Bay and Portersville Bay. A number of islands (South and North Rigolets, L'Isle Chaude, Long, Big, Barton, Marsh, Isle aux Herbes, et cetera) are remnants of this deltaic plain. The deterioration of these islands started when the Escatawpa River switched course and became the tributary of the Pascagoula River.

Miniature sandy barrier islands developed along the deteriorating and retreating abandoned Escatawpa delta front (Grand Batture Islands) but repeated hurricanes destroyed most of them. At the same time, the marshy delta-remnant shores also suffered serious erosion and retreated northwestward (South Rigolets Island).

Holocene sedimentation in the Mississippi Sound resulted in the formation of lagoonal deposits 12-36 feet thick. In the zone along the southern margin of the present Mississippi Sound most exposed to the waves of the open Gulf, shoals and barrier islands developed (Horn, Petit Bois, Dauphin Islands). The islands, capped by beaches, dunes, and marshes were and are in constant migration. In addition, storm erosion periodically reduces the island ends to shoal only to be rebuilt later in fair weather conditions.

Geological Formations and their Relationship to the Conditions of the Land Surface

The Citronelle Formation (Figure 6) consists of brick red, yellowish brown, pale yellow silty sands, sandy silts, sandy conglomerates, and minor amounts of clay. The Citronelle is widespread between the Mississippi River and the Atlantic Coast and is widely used for construction purposes. Total thickness of the well consolidated but not cemented Citronelle Formation varies generally between 40-120 feet. In the study area, a Citronelle area lies only 1-2 miles north of the shores of Grand and Portersville Bays. The east-west length of the Citronelle exposure is about seven miles. A gently rolling surface at about a 50-70 foot elevation above sea level caps the Citronelle. This surface is disected by fairly steep-walled gullies and valleys. Oval-shaped, gently sloping minor depressions are common in the undisected Citronelle surface areas. The Citronelle block rises abruptly from the flat coastal area of the Grand Bay Swamp, 6-8 degree slopes being common on this escarpment.

Consolidated silty sands and sandy silts form most of the Prairie Formation. Near and on the surface, because of oxidation, the original grayish color changes into characteristic pale yellow, pale brownish yellow. The Prairie usually is 10-35 feet thick. In the subject area, it forms an evenly sloping, almost flat, undisected surface usually at 5-15 feet above sea level. Pascagoula, Moss Point, the Bayou Casotte Industrial Park, and Bayou La Batre are all located on the dry Prairie surface. Along most of the coast of the subject area, the Prairie surface is covered by a relatively thin layer of marsh-swamp deposits of Holocene age. Under the Mississippi Sound, presence of the Prairie Formation has been established in a number of coreholes between Pascagoula and Petit Bois Island.

Although the Biloxi Formation does not crop out in the subject area, it has been found under the Mississippi Sound in coreholes. It is a gray, muddy-sandy, sandy-muddy unit, usually rich in microfauna and well consolidated. In this area its thickness was only about 19-20 feet. Depths below sea level: 36-53 feet; below Sound bottom: 27-50 feet.

The fringes of the mainland and the central areas of the barrier islands are covered by wetland deposits of Holocene origin. The greatest width of this facies is five miles but at few locations is the width of the wetland zone less than one mile. One of the few such locations can be found south of Pascagoula where between Lake Yazoo and Bayou Chico, no wetlands skirt the mainland shore for a distance of about two miles. Due to the very gentle slope of the underlying Prairie surface, it may be assumed that the thickness of the wetland deposits does not exceed 15-20 feet over most of the area and is less than 10 feet in the northern parts.

Swamps (tree vegetation) and marshes (without trees, mostly grasses and reeds) are intricately intertwined along the mainland coast. The largest salt-marsh area is found between the Bayou Casotte Industrial Park and the Mississippi-Alabama state line. Northward, the salt marsh grades into freshwater marshes and swamps, the largest swamp area being Grand Bay Swamp north of Grand and Portersville Bays. Fringed by salt marshes along bay shores, this 1-1.5-mile swamp has extremely dense vegetation with the water cover, except in natural channels, not exceeding 2-3 feet.

Sediments of marshes and swamps are rich in woody-peaty organic material and muddy deposits. Due to sandy source areas, the sediments in the subject area contain a larger-than-average proportion of sand fraction. Both deposit types are unconsolidate, highly compactible, contain a large proportion of water, and represent the poorest engineering soil types for foundation purposes.

Due to the low energy conditions, most of the mainland shores lack sandy beaches. The best developed sand beaches are found northwest and northeast of Point aux Chenes but even there the beach width does not exceed 30-40 feet. Miniature sand dunes cap the backshores behind the beaches. High energy conditions and active littoral sand drift helped to develop the offshore barrier islands. Petit Bois Island, in the southern part of the subject area, contains well developed beaches, especially along the Gulf shore. However, along the low-energy Sound shore, the beaches are much narrower. Dune elevations on this island range between 5-18 feet. Remnants of the Holocene Escatawpa delta in the Mississippi Sound, being better exposed to waves, developed beaches on small sandy islands (Grand Batture Islands) but more recent erosion has eliminated most of them.

The high energy environment which created and maintained the Mississippi Sound offshore barrier islands also maintains sandy shoal areas (Figure 7) between the islands and behind them (Horn Island and Petit Bois Passes). Remnants of the Grand Batture Islands and the shoal area in front of them are also outlined by sandy-bottom sediments. Coastal recession and the winnowing of the muddy sediments also resulted in remnant sandy-bottom zones around the Point aux Pins Peninsula, the southern end of Isle aux Herbes, and south-southeast of Bayou La Batre.

The greatest clay-mud concentrations are found in the deepest parts of the Mississippi Sound least disturbed by wave and tidal current activity. The muddy-bottom zone between Petit Bois Island and Point aux Chenes; and Dauphin Island and the Bayou La Batre mainland area is 4-7 miles wide at its greatest.

Zones of mixed sandy-muddy bottom deposits up to two miles wide exist between the predominantly sandy-bottom and the predominantly muddy-bottom areas. They are found along the margin of the sandy belt skirting the mainland shore and along the sandy-bottom zone north of the barrier islands and the intervening sandy shoals. This bottom category is due to the mixing processes by wave activity and bottom currents.

Tectonic Behavior of the Subject Area - Movements in Past; Possible Movements in Future

The Mississippi-Alabama coastal zone has experienced upward movement in the past. The fluvial-delatic deposits of the Citronelle and the Prairie Formations have been elevated to higher positions than they originally occupied in the past. During their original deposition, these formations were laid down close to sea level. Such subsequent movements usually occur along a fault line. The coastal zone of the central-eastern Gulf of Mexico is characterized by the predominance of east-west, southwest-northeast, and southeast-northwest trending "coastwise" faults, along which movements have been going on since the Cenozoic Era. Some faults are shown by geodetic measurements and the tracing of earthquake hypocenters to be active at present.

One very likely surface expression of a fault line exists along the southern margin of the Citronelle area, north of Grand and Portersville Bays. The southward-facing surface scarp of the Citronelle belt, with a maximum 6-8 degree slope inclination, strikes completely straight for a distance of 7-8 miles in an east-west direction. Similar scarps, also suggestive of fault origin, are located along the Citronelle area north of St. Louis Bay and along earlier Pleistocene deposits north of Biloxi and Ocean Springs, Mississippi.

Tectonically, the subject area is much less active than the adjoining coastal Louisiana area, but the possibility of slow (long-term) or sudden (earthquake-related) movements is not excluded. A minor (Mercalli-Scale V-VI) earthquake occurred in the central part of the Mississippi coast during the decade of 1955-65. A similar-sized quake happened at the same time near Baton Rouge, Louisiana.

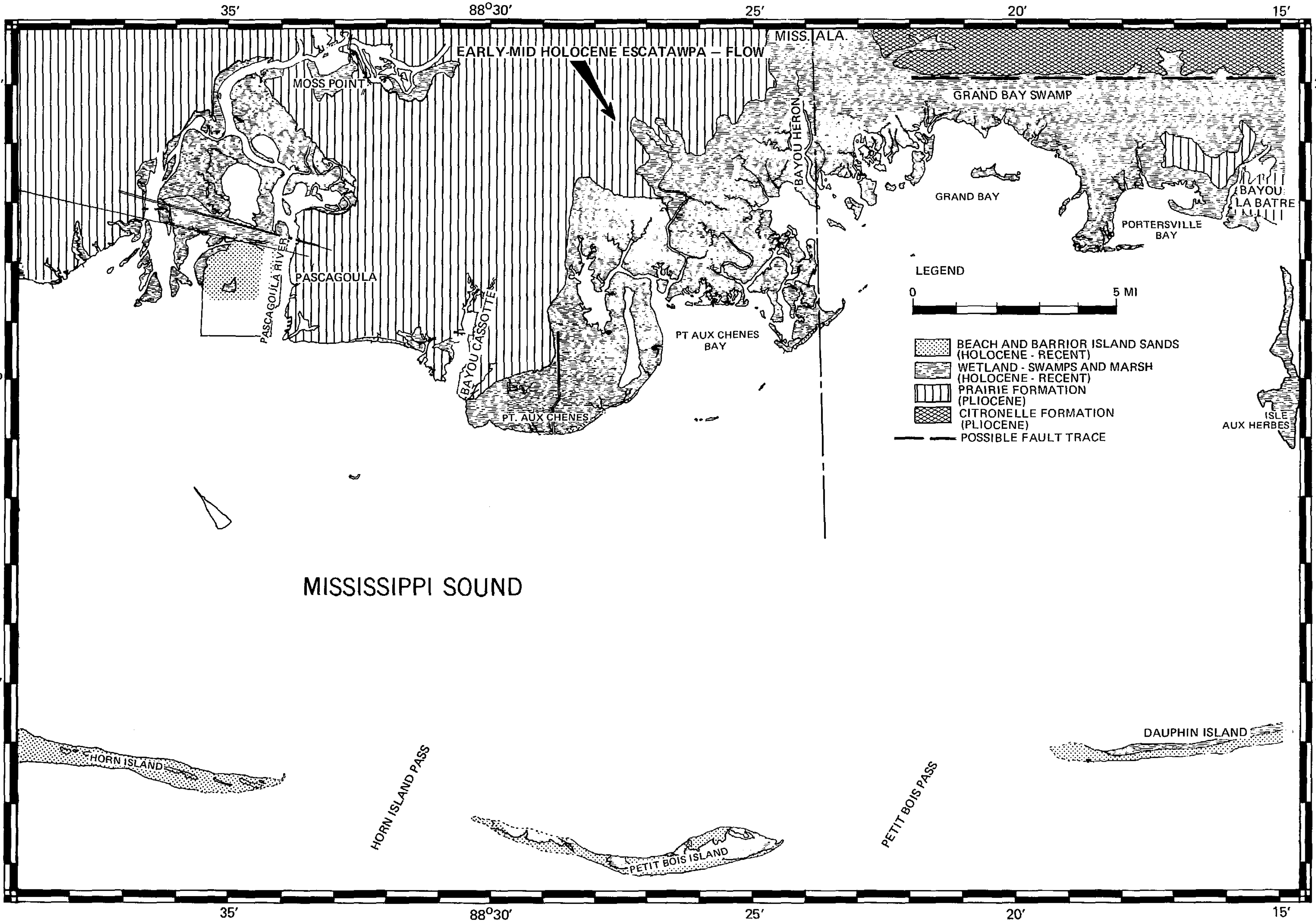


FIGURE 6. GEOLOGY OF PASCAGOULA - BAYOU LA BATRE MAINLAND.

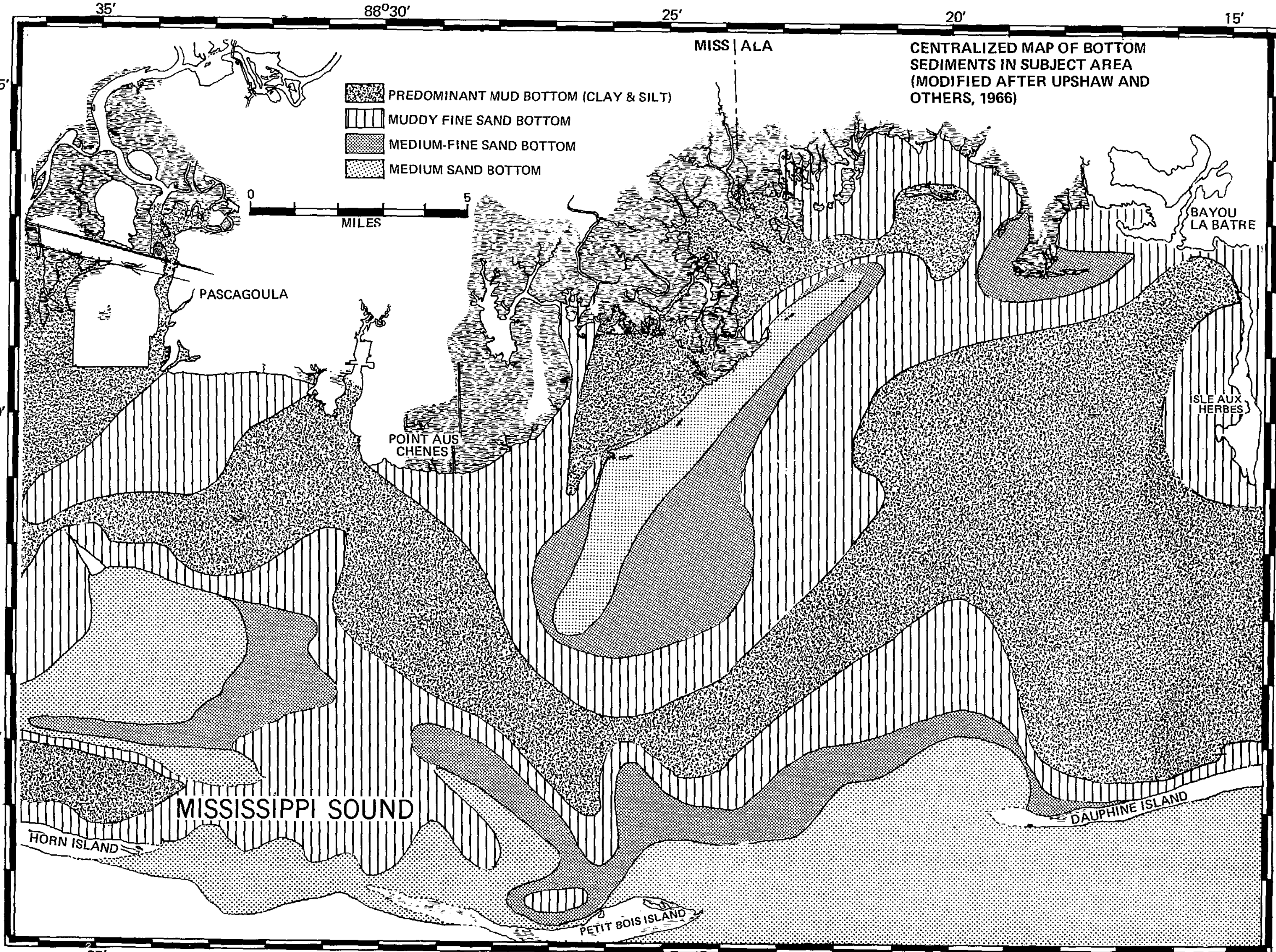


FIGURE 7. SEDIMENT DISTRIBUTION, EAST MISSISSIPPI SOUND.

Geological Cross Section Between Head of Bayou Casotte and West End Petit Bois Island

The cross section (Figure 8) has been prepared from assorted drilling data gathered and compiled by Gulf Coast Research Laboratory and from a U. S. Geological Survey published report on Jackson County, Mississippi. The Gulf Coast Research Laboratory information from four drillholes is, at the present time, far from complete but still serves as a guideline to the stratigraphy of the offshore areas between the mouth of Bayou Casotte and the west end of Petit Bois Island. The northenmost drillhole, P-1, was located 1.3 miles south of the mouth of Bayou Casotte; and the southernmost drillhole, P-4, on the north shore of the west tip of Petit Bois Island. In the following, the lithology of the encountered geological formations along the cross section line is discussed in some detail.

The Pascagoula Formation (Miocene) consists of greenish gray, well consolidated, stiff clays; silty, sandy, and occasionally with shell fossils. Sand content occasionally is higher; and at greater depth, sand lenses and layers are intercalated with the silty clays. The surface of the Pascagoula is uneven due to erosional disection after deposition by streams in Citronelle times. One major erosional channel, shown at the north end of the cross section, can be attributed to an ancient Pascagoula River channel.

Reddish and yellowish-brown sandy gravels, gravelly sands, silty sands make up the Citronelle (Mid-Late Pliocene) and earlier Pleistocene deposits on land with plant fragment inclusions being not uncommon. U. S. Geological Survey data indicate a large Citronelle channel-fill is present at the mouth of Bayou Casotte. Some of the muddy-sandy, sandy-muddy deposits in drillholes P-1, P-2, and P-3 above the Pascagoula surface, in all likelihood, belong to one or both of these deposit types.

Found only in drillholes P-1 and P-4, the Biloxi Formation (Late Pleistocene) is greenish-gray, gray muddy sand, sandy muds with occasional sand inclusions; usually moderately to well consolidated, although not as well as the Pascagoula clay. Macrofossils (shells, gastropods) are occasionally abundant; microfossils (foraminifers) are common. The absence of the Biloxi from the central Sound areas, in all probability, is due to fluvial erosion during Prairie times, streams having excavated the pre-existing Biloxi beds during a regressive period.

Light olive gray, grayish blue-green mud, muddy sand, sandy mud, the Prairie Formation (Late Pleistocene) is moderately consolidated. Toward the surface of the unit, grayish-orange, orange streaks were occasionally found, this being evidence that the top few feet of the unit were exposed to oxidation before the Holocene transgression. Plant fragments occasionally are also found in this fluvial-alluvial unit, formed in flood plains and river channels. The surface of the Prairie is a gently undulating plain except where major stream channels have excavated it during the very end of the Pleistocene and during the early Holocene times. Such a stream channel probably did not cross the line of cross section but was definitely present west of it in the continuation of the Pascagoula River and, in all probability, also to the east following the early Escatawpa course.

Holocene sediments are represented by unconsolidated, water-soaked gray-greenish gray muds and sandy muds in drillholes P-1, P-2, and P-3. Further to the south, in drillhole P-4, sand predominates. In the top section of P-3, muddy sand forms the uppermost Holocene-Recent unit at 20-25 feet below sea level. The presence of Petit Bois Island nearby is responsible for the presence of a medium-fine sand unit between 3.5 and 26.5 feet in P-4, underlain by clay and muddy sand, probably also Holocene. Macrofossils (shells, shell fragments) and microfossils (foraminifers, ostracods) are common in the soft Holocene sound-bay deposits.

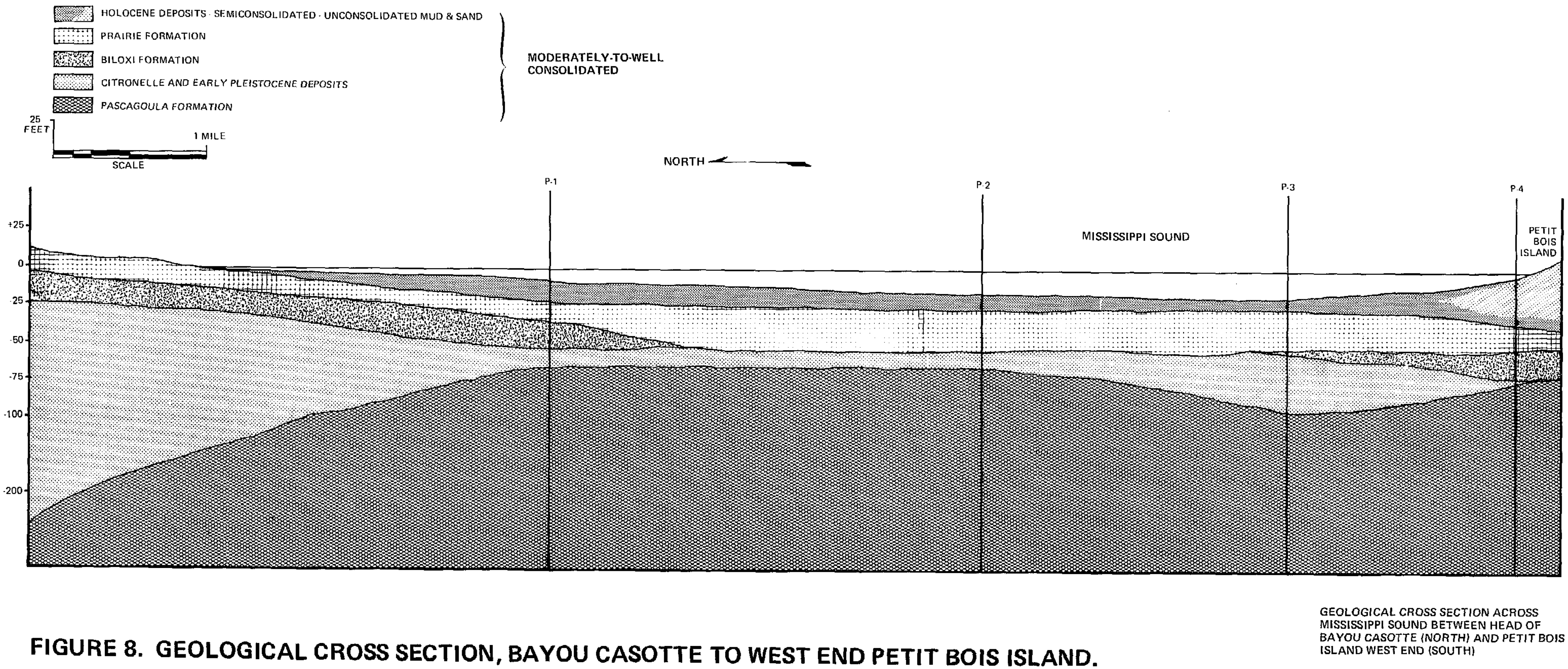


FIGURE 8. GEOLOGICAL CROSS SECTION, BAYOU CASOTTE TO WEST END PETIT BOIS ISLAND.

TABLE I

FORMATIONS OF MISSISSIPPI GULF COAST

Age	Formation	Thickness m (ft)	Lithology and Depositional Facies
Recent	--	Not applicable	Unconsolidated sands, silty sands, gravels, muddy sands, dark muds, peats (mainland beaches, barrier islands, inter-island shoals, sounds, bays, estuaries, river channels, swamps, marshes, oyster reefs)
Holocene	--	0-15 m (0-45 ft); mostly 5-10 m (16.5-33 ft) (Maximum: under islands, Mississippi Sound, bay-entrance channels)	Same as Recent and sands of mainland barrier ridge complex (S. Hancock County)
Pleistocene			
(Sangamon Interglacial-? Early Wisconsin Glacial)	Prairie	3-10 m (10-33 ft)	Semiconsolidated silty sands, fine and medium sands, sandy gravels, silts, peats (fluvial-alluvial complex)
(Sangamon Interglacial)	Gulfport	3.5-8 m (12-27 ft)	Fine and medium sand, muddy fine sand dunes, beaches, shoreface mainland barrier ridges
(Sangamon Interglacial)	Biloxi	4-16 m (13-53 ft)	Semiconsolidated, often fossiliferous muddy fine sands, clayey fine sands, sandy muds (shallow nearshore marine)
Earlier Pleistocene (Interglacial? Glacial?)	Not defined	20 m (66 ft) (?)	Silty sands, clayey sands, muddy sands, sandy muds, fine sands, some clay and peat (fluvial-alluvial complex)
Pliocene (-Preglacial Pleistocene?)	Citronelle	12-48 m (40-160 ft)	Sandy gravels, silty sands, fine and medium sands (fluvial-alluvial complex)
Miocene	Pascagoula ("Graham Ferry" not considered a separate formation above Pascagoula Formation)	Maximum over 490 m: (1300 ft) (?)	Consolidated clays, silty clays, silty sands, fine sands, sandy muds (estuarine, fluvial and lagoonal complex)

Gulf of Mexico Circulation

The circulation in the Gulf of Mexico is complex and not fully understood. The large scale circulation in the Gulf of Mexico is attributable to four major factors: Yucatan Current, tides, winds, and river discharges. There is considerable variability in the magnitude of these four factors, their acting in harmony to reinforce each other or in opposition to cancel each other's influence; and superimposed upon this interaction and varying in scale are transient phenomena that may abruptly change the existing circulation pattern. An assessment of the circulation and environmental conditions in the northeast Gulf area where it is proposed that a Superport monobuoy be located, must first be considered in terms of its relationship to the total Gulf circulation.

The Loop Current, a major feature of the eastern Gulf, is a continuation of the Yucatan Current which has its beginning in the western Cayman Sea. Entering the Gulf of Mexico through the Yucatan Straits, the Loop Current penetrates some varying distance into the Gulf then turns in a clockwise direction and exits through the Florida Straits. The Current exhibits great variability seasonally and annually in both magnitude and course.

After entering the Gulf, the Loop Current advances in a north-northeast direction sometimes almost reaching the Mississippi River Delta. A series of hydrographic cruises has revealed a northward progression of the Current from the southeastern Gulf in mid-winter to the edge of the continental shelf off the Mississippi River Delta in August. Direct current measurements taken during spring and summer indicate speeds up to 250 cm sec^{-1} in the core of the Current.

The path of the Loop Current appears to be directed to some degree by the topography of the Gulf basin. The vertical extent of the Current entering the Gulf is dictated by the relatively shallow sill depth of 2,103 meters (6,900 feet) of the Yucatan Straits. This non-steady flow of the Current is characterized in the development of meanderings of the Current.

Large eddies, frequently formed from the meanderings of the Current, separate and drift into the western Gulf and decay over periods of three to six months. No significant permanent or semi-permanent currents exist in the western Gulf with the exception of a southerly-oriented boundary current along the west Louisiana and Texas coasts.

Figures 9 through 14, illustrating the surface streamlines and the corresponding current magnitude, depict the waxing and waning of the Loop Current and the subsequent formation of eddies. It should be pointed out that a specific volume of water is being transported between adjacent pairs of streamlines; thus where the distance between the lines narrows, the current of necessity increases in order to account for the continued transport of the specified volume. The opposite is also true; i.e., where the distance between the lines widens, a reduction in current speed is produced.

Figure 9 shows that by February the Loop Current intruded far into the Gulf with its influence being felt even further north. A small eddy appears to have formed off the northwest extent of the Loop Current. On the east side of the Yucatan Straits evidence of a counter-current along the west Gulf-side of Cuba exists that, in actuality, is the formation of an eddy which will become internal to the Current as it intensifies. On the west Gulf-side of the Yucatan Straits the bathymetry rises sharply to a relatively shallow depth. As the Yucatan Current (Loop Current as it enters the Gulf) confronts the steep slope, there is an upward movement of the deep waters to override this barrier. A strong upward movement of the water or "upwelling" is produced bringing nutriently rich material from the bottom. The enrichment of the surface and water column by the upwelling process attracts numerous marine species. The Campeche Bank has long been established as a rich fisheries area as a result of the upwelling process.

In June 1966 (Figure 10) the Loop Current intruded as far north as 28°30' north latitude. Current velocities in the core of the Current reached 3.5 knots (4.03 mph). Northwest of the Yucatan Straits located at about 26°45'N, 90°15'W, a clockwise eddy that separated from the Loop Current is shown.

The pattern of streamlines in Figure 11 shows that in June 1967, the Loop Current weakened leaving a well-developed eddy. The difference in stage and intensity from the 1966 situation displays the considerable annual variability.

The configuration of streamlines from the August 1966 hydrographic cruise (Figure 12) is an excellent illustration of a number of processes taking place. The Loop Current appears to follow the bottom topography of the Campeche Bank bending in a westerly manner after entering the Yucatan Straits. The northerly extent of the Current parallels the continental shelf of east Louisiana, Mississippi, Alabama, and west Florida. An eddy which will eventually drift into the western Gulf is in the process of being formed as evidenced by the narrow constriction below the broad oval-shaped upper extent. The Current is declining in intensity and is in the process of moving to the southeast.

From the streamlines constructed from data collected in October 1966 (Figure 13) a pattern similar to August 1966 is shown but the orientation of the axis is more to the northwest. The northern extent of the Loop Current again follows the continental shelf from west of the Delta northeast into the DeSoto Canyon and then turns abruptly to the south.

Figure 14 is a composite picture constructed from three different cruises. The resulting streamlines show a large eddy situated over the Mississippi Cone. The Loop Current in its weakened or "relaxed" state enters through the Yucatan Straits and immediately turns east and exits through the Florida Straits.

The appearance of ripples, scour marks, and lineations in the sediments from photographs of the bottom taken in the area of the Mississippi Cone evidences the existence of significant bottom currents. Current speeds up to 19 cm sec^{-1} were obtained from current meters mounted near the bottom. The existence of substantial currents was suspected as biological samples taken prior to the use of cameras and current meters contained sessile organisms that depend upon currents to transport food to them. Insufficient information prevented an attempt to determine the orientation of the current. It should suffice here to state that data substantiating the existence of bottom currents in the abyssal depths of the Gulf of Mexico have been collected.

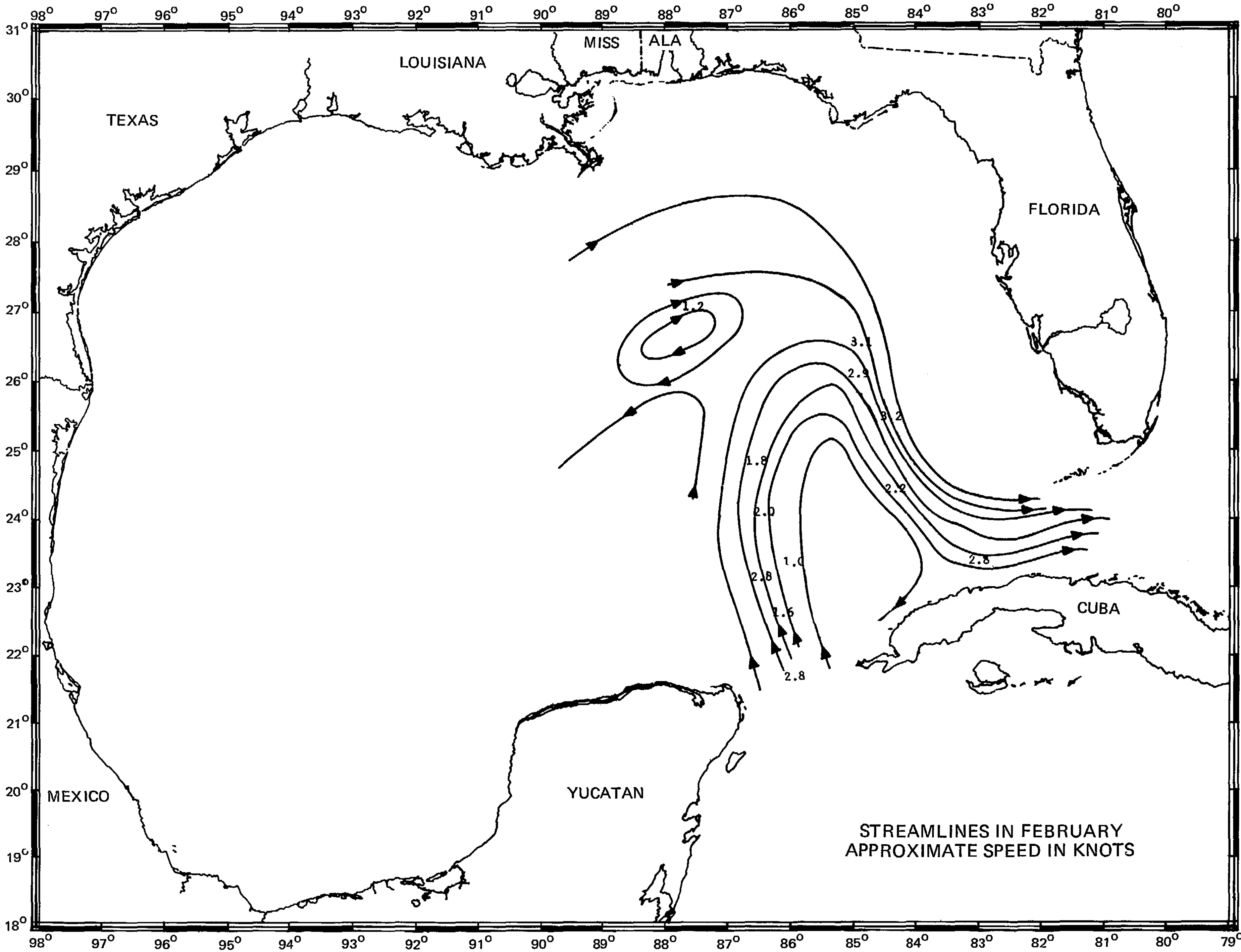


FIGURE 9. LOOP CURRENT STREAMLINES, FEBRUARY, 1962.

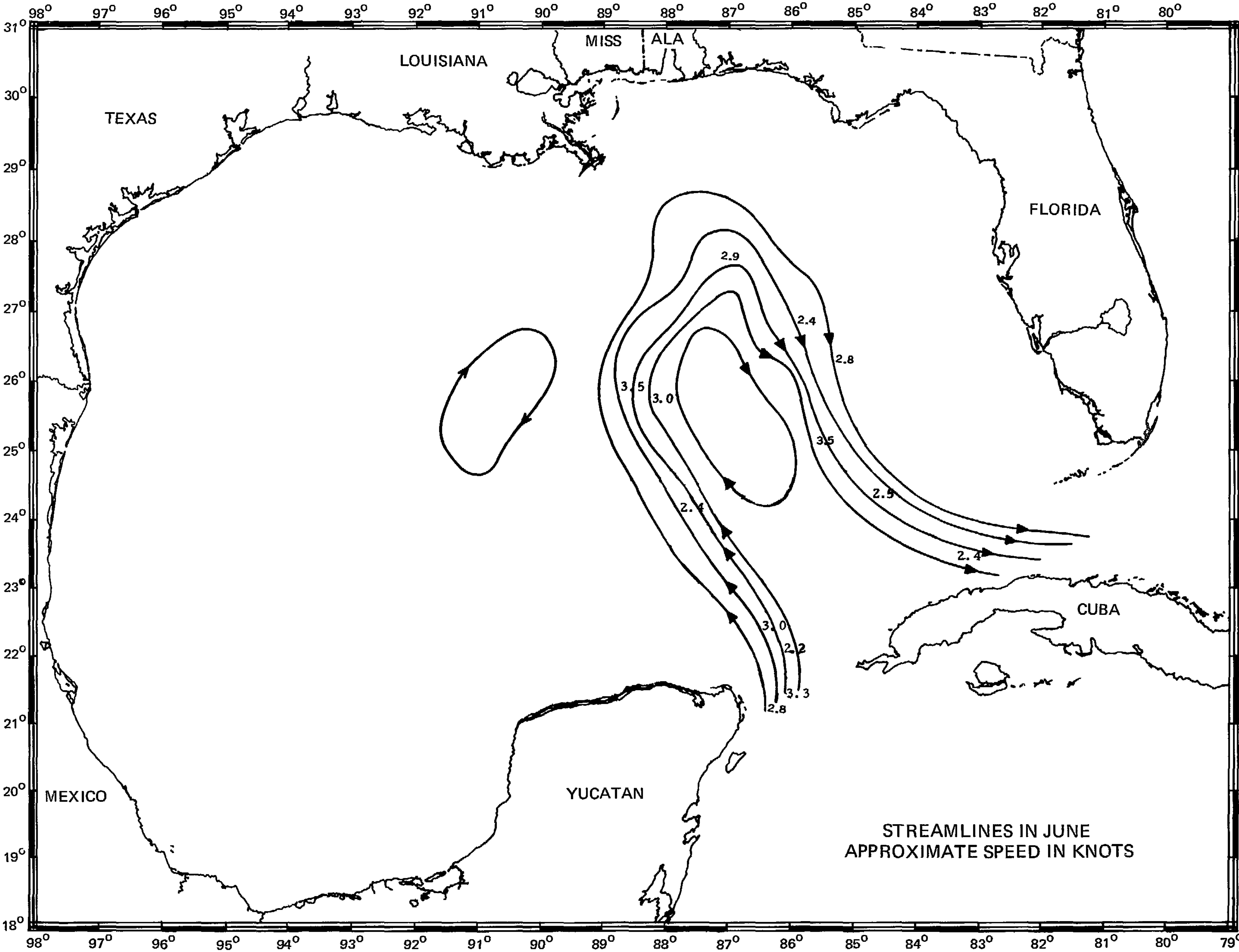


FIGURE 10. LOOP CURRENT STREAMLINES, JUNE, 1966.

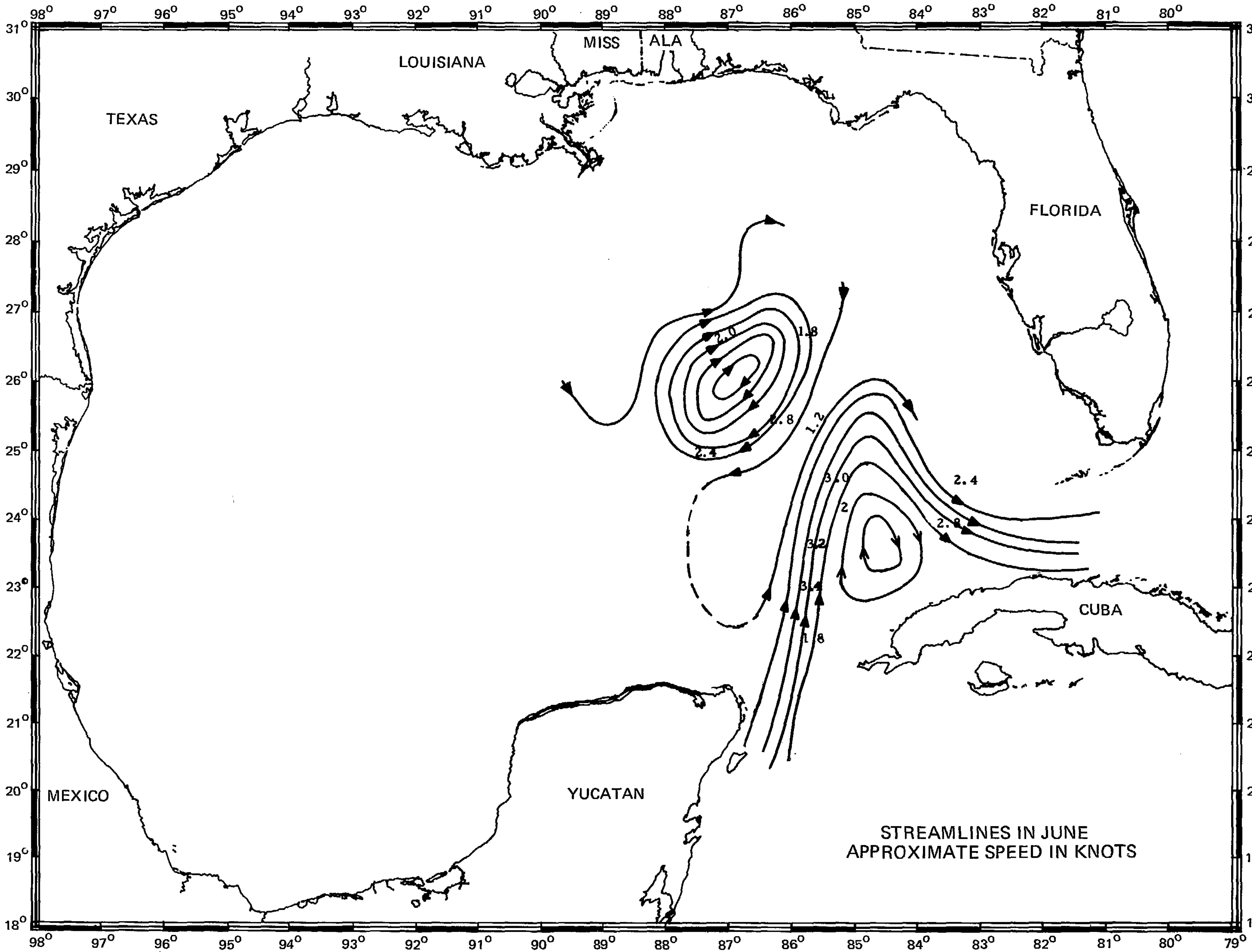


FIGURE 11. LOOP CURRENT STREAMLINES, JUNE, 1967.

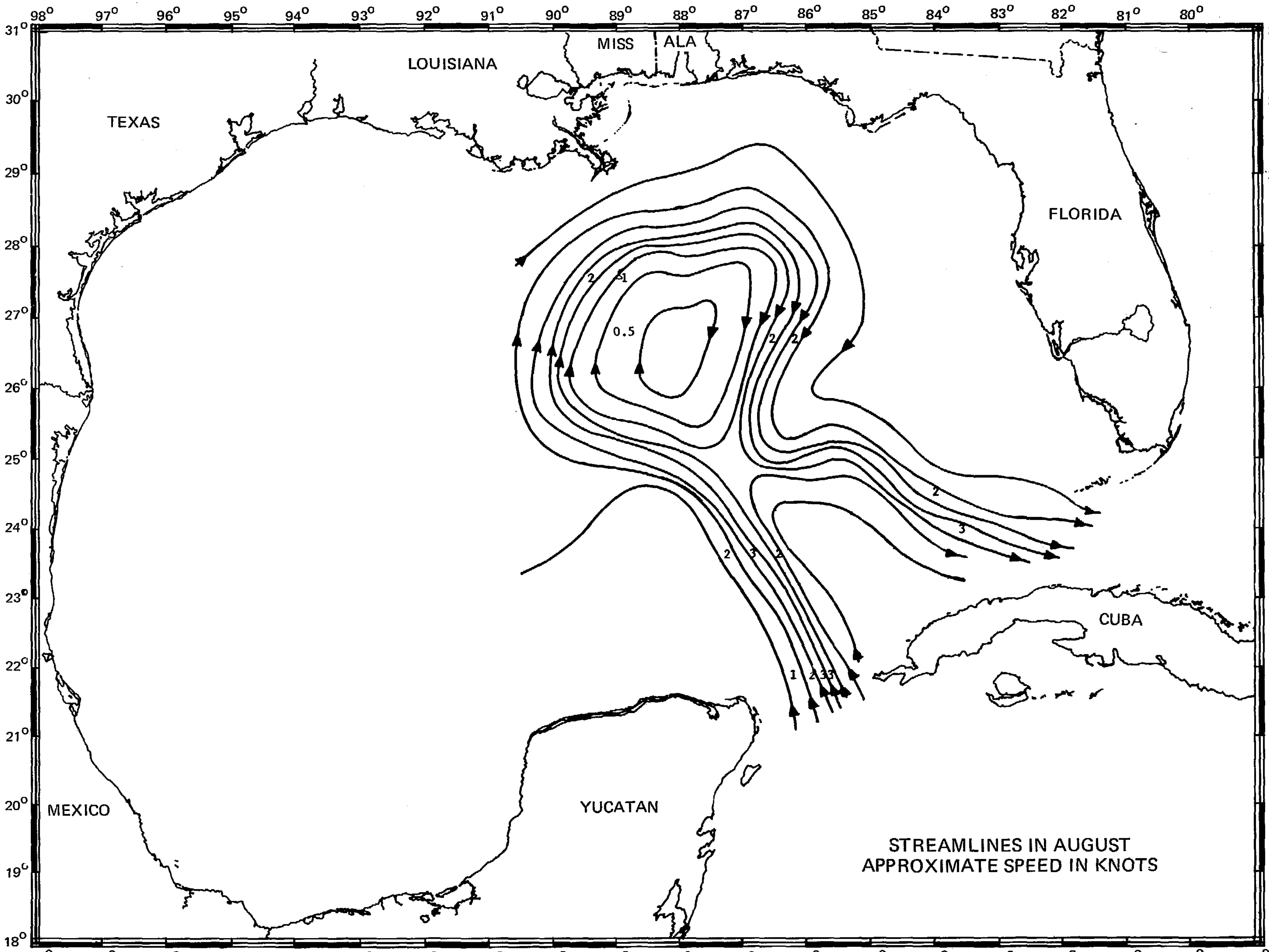


FIGURE 12. LOOP CURRENT STREAMLINES, AUGUST, 1966.

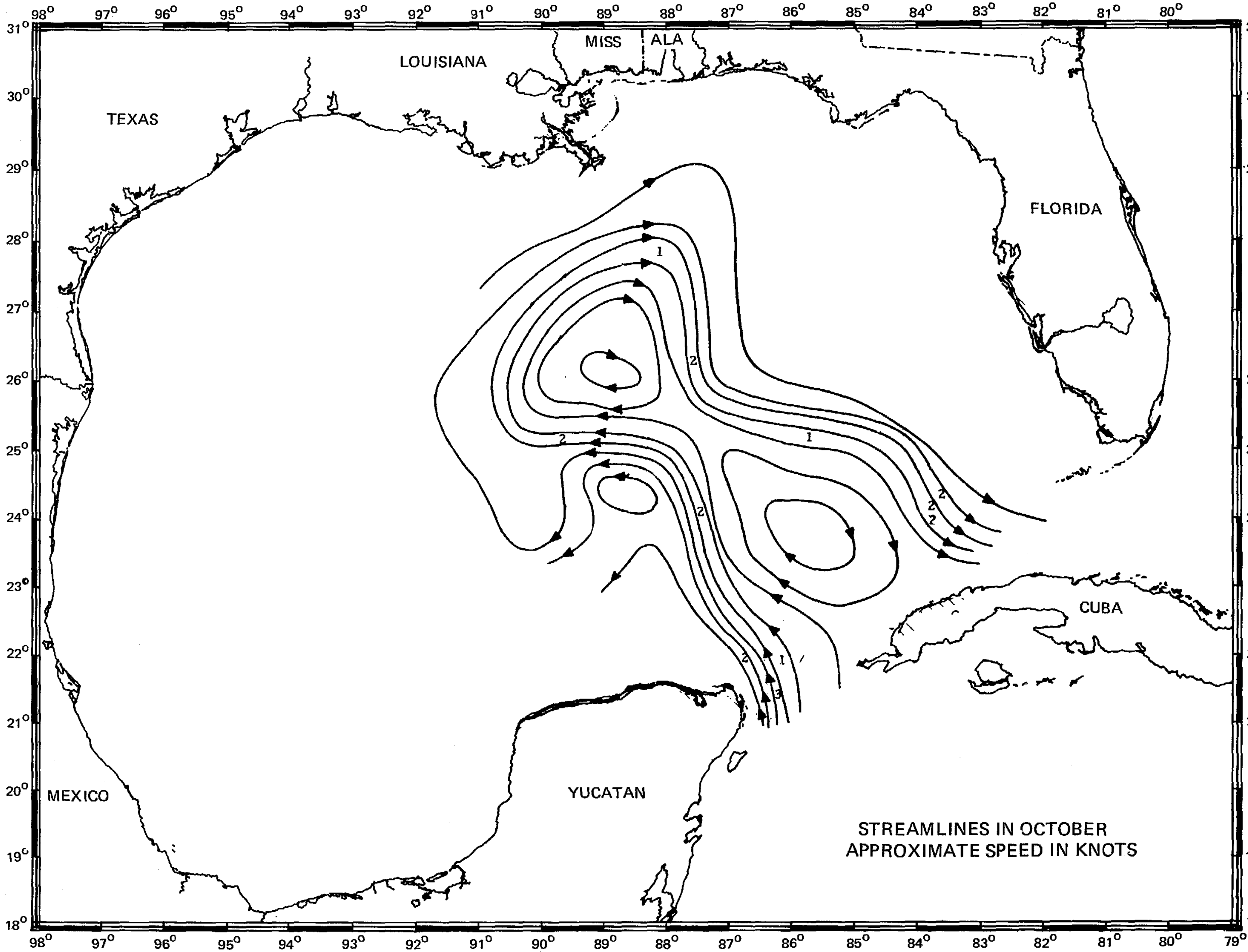


FIGURE 13. LOOP CURRENT STREAMLINES, OCTOBER, 1966.

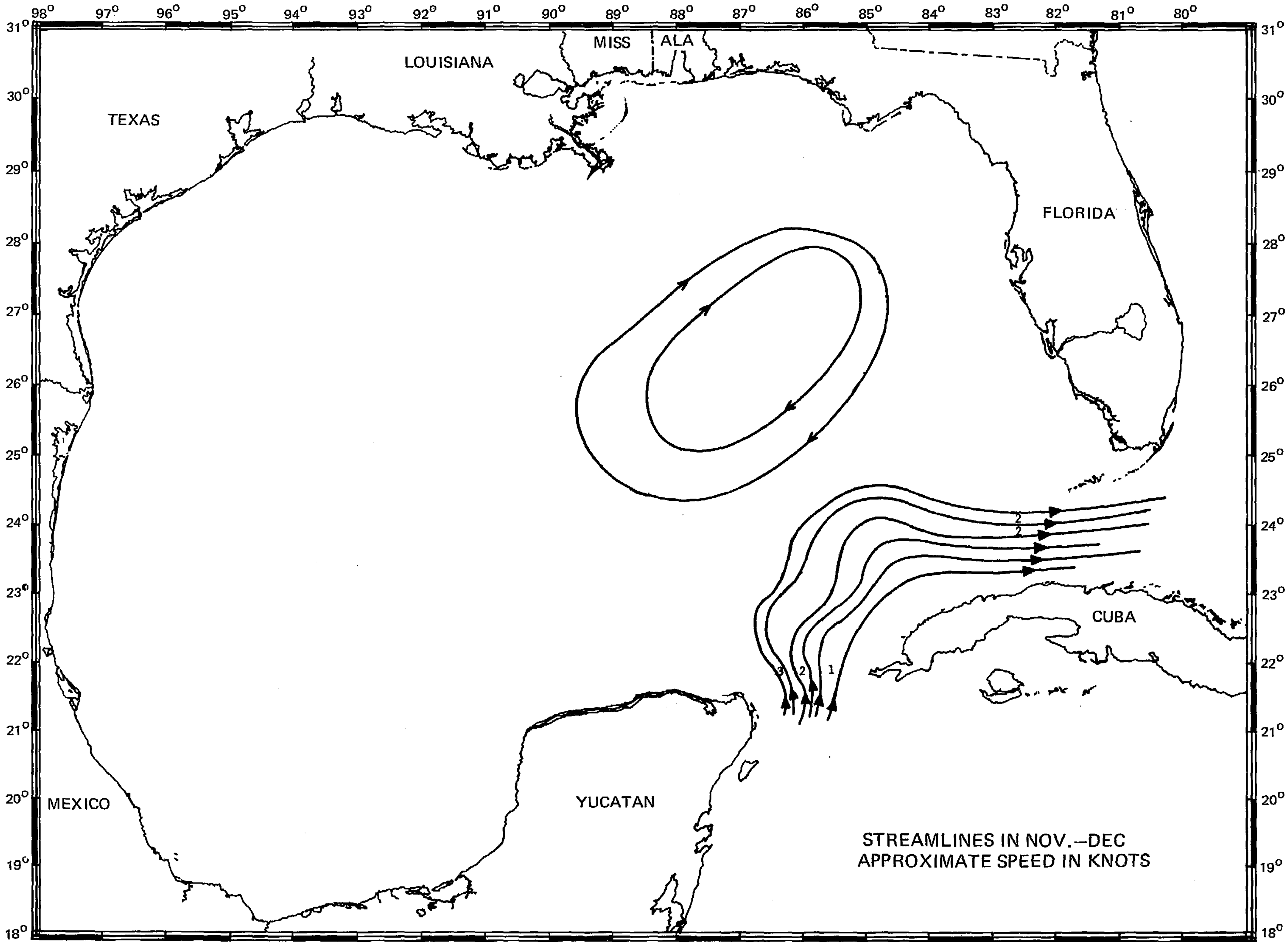


FIGURE 14. LOOP CURRENT STREAMLINES, DECEMBER, 1965.

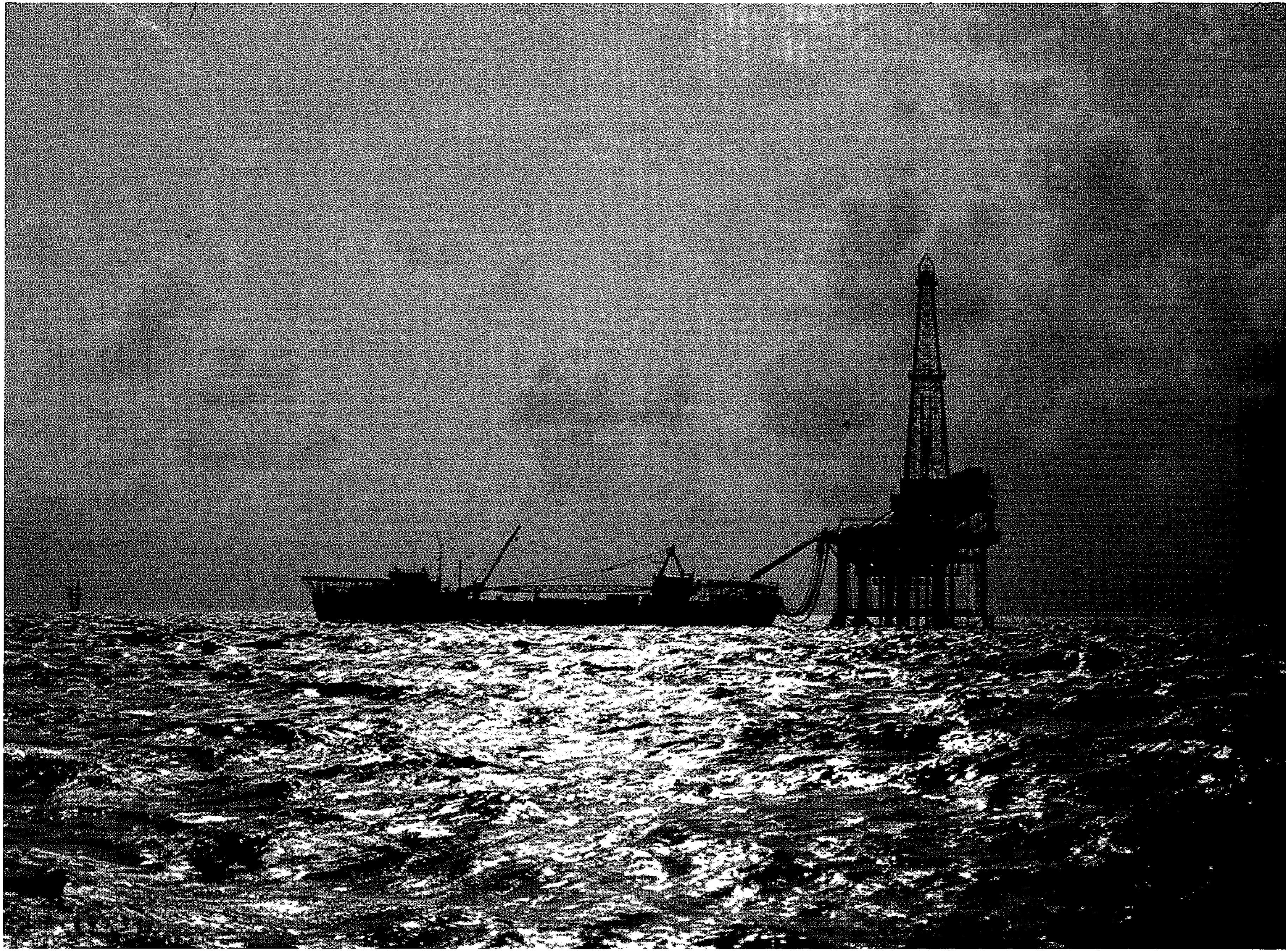


PHOTO 2. OFFSHORE OIL RIG AND SUPPORT SHIP.

Charles K. Eleuterius

Shelf Circulation

From 1961 through 1966 a hydrographic study was conducted over the northeast Gulf continental shelf from west of the Mississippi Delta to east of Pensacola, Florida, to determine the major circulatory features and distribution of physical properties. A characteristic of the circulation over this region of the shelf is its short-term variability.

The area shows strong salinity gradients especially in the vicinity of the Mississippi River Delta where in a distance of 10 miles from the Delta, surface salinities range from near 0.0 parts per thousand to 36.0 ppt. High-salinity cells appear to be permanent features in the area during the winter with an intrusion of low-salinity waters which spread eastward over the shelf during late spring and early summer. The near-shore shelf area experiences a general freshening earlier due to the earlier occurrence of the peak discharge period of the independent streams and smaller rivers governed by local climatic conditions.

Convergence lines identified by strong salinity gradients and sharp color discontinuities are detected 60 to 70 miles east of the Delta during spring. On at least one occasion the discharge and mixing of the Mississippi River waters with those of the open Gulf were so intense that a distinguishable vertical difference in elevation was observed along a long stretch of the convergence line.

During summer, surface temperatures decrease seaward ranging from 33C in the nearshore legions to 29C in the area near the continental slope. During the winter this trend is reversed with temperatures rising in the seaward direction. Winter surface temperatures range from 10C in the nearshore area to 22C at the edge of the continental shelf.

Because horizontal differences in water density are possible only in the presence of currents, water density is especially useful in delineating current patterns. In Figures 15-22 isopycnals, lines of constant density, are depicted based on calculations of the anomaly of potential density from measurements of temperature and salinity. The isopleths are labeled showing the appropriate density values with the larger numbers corresponding to the greater density. In addition to the labeling of the isopleths, the gradients are emphasized by employing shades of color. While in most instances the heavier water is denoted by the darker shade, this does not hold true throughout the figures due to the occurrence of strong gradients requiring more intervals than available distinguishable shades.

In the outer shelf areas it can be assumed that the currents are nearly geostrophic; however, this assumption cannot be extended to the nearshore regions that are tide dominated and subject to the influence of river discharges.

In January (Figure 15) a tongue of lighter water is seen moving offshore in a southeast direction. A flow of heavier sea water is shown flowing westward over the shelf west of DeSoto Canyon. The presence of this heavier water mass over the shelf appears to be a semi-permanent feature during the winter.

The high rate of freshwater discharge from the Mississippi River and its extent of influence on the hydrography of the shelf are obvious in the data collected during the spring (Figure 16). The heavier, high-salinity water is shown moving westward north of the lighter water and then southward almost severing the elongated tongue of lighter water. The movement of the lighter water to the east is probably due to the drag placed upon it by the heavier water that moves approximately parallel to the shelf.

The hydrographic cruise of April 1964 (Figure 17), while limited in coverage, does show the northward deflection of the Mississippi River outflow through Pass a Loutre. The extent of the heavier water intrusion over the shelf is clearly shown but because of lack of data, the presence of the nearshore westward flow is not determinable.

The westward flow over the shelf from the DeSoto Canyon area was again present during May 1965 (Figure 18). A narrow tongue of lighter water projects eastward from the area of Chandeleur Islands and turns counterclockwise to a northeast orientation.

The spatial distribution of density during May 1964 (Figure 19), while similar to the May 1965 pattern, was obviously affected by higher rates of freshwater outflow. The westward flow of the heavier, saline water moved southward offshore and was separated from the mainland by lighter, fresher waters from Mobile Bay and Pascagoula River moving eastward along the shore. The paths of the isopycnals also show that there was considerable outflow from Mississippi, Chandeleur, and Breton Sounds.

The surface isopycnals for June-July 1964 (Figure 20) depict an eastward flow of the Mississippi River discharge from Pass a Loutre somewhat aligned with the shelf. An arm of heavier water intrudes over the shelf from the area of DeSoto Canyon separating the outflow of the Mississippi River from that attributable to Mississippi Sound, Mobile Bay, and Pensacola Bay. The arm turns in a cyclonic (counterclockwise) fashion encircling the lighter river water. The elongated tongue of fresh water from the northern mainland extends east-southeast beyond DeSoto Canyon and over the Florida Shelf. To the north of this outflow and moving in a westward direction from east of Panama City, Florida, is a mass of heavy, high-salinity water. An isolated lens of heavy water located due south of Mobile Bay is discernible.

The density isopleths constructed from the July 1965 data (Figure 21) show a cell of lighter water southwest of Panama City, Florida. The discharge from South Pass and Pass a Loutre projects eastward, then turns cyclonically as it is entrained by the heavier water that has flowed westward along the northern mainland, then turns encircling the lighter water. The cyclonic eddy that is portrayed here appears to be a semi-permanent feature of the shelf area south of the states of Mississippi and Alabama.

The eddy was not present over the shelf during August-September 1964 (Figure 22). The discharge from the Mississippi River was deflected to the northeast combining with an outflow from the west end of Mississippi Sound. The lighter waters east of DeSoto Canyon are apparently continuations of the Mississippi

River outflow that have been bisected by the intrusion of the heavier water mass moving northward following the Canyon.

The semi-permanent cyclonic eddy, the Mississippi River discharge, and the presence of the Loop Current parallel to the shelf are conceptually depicted in Figure 23.

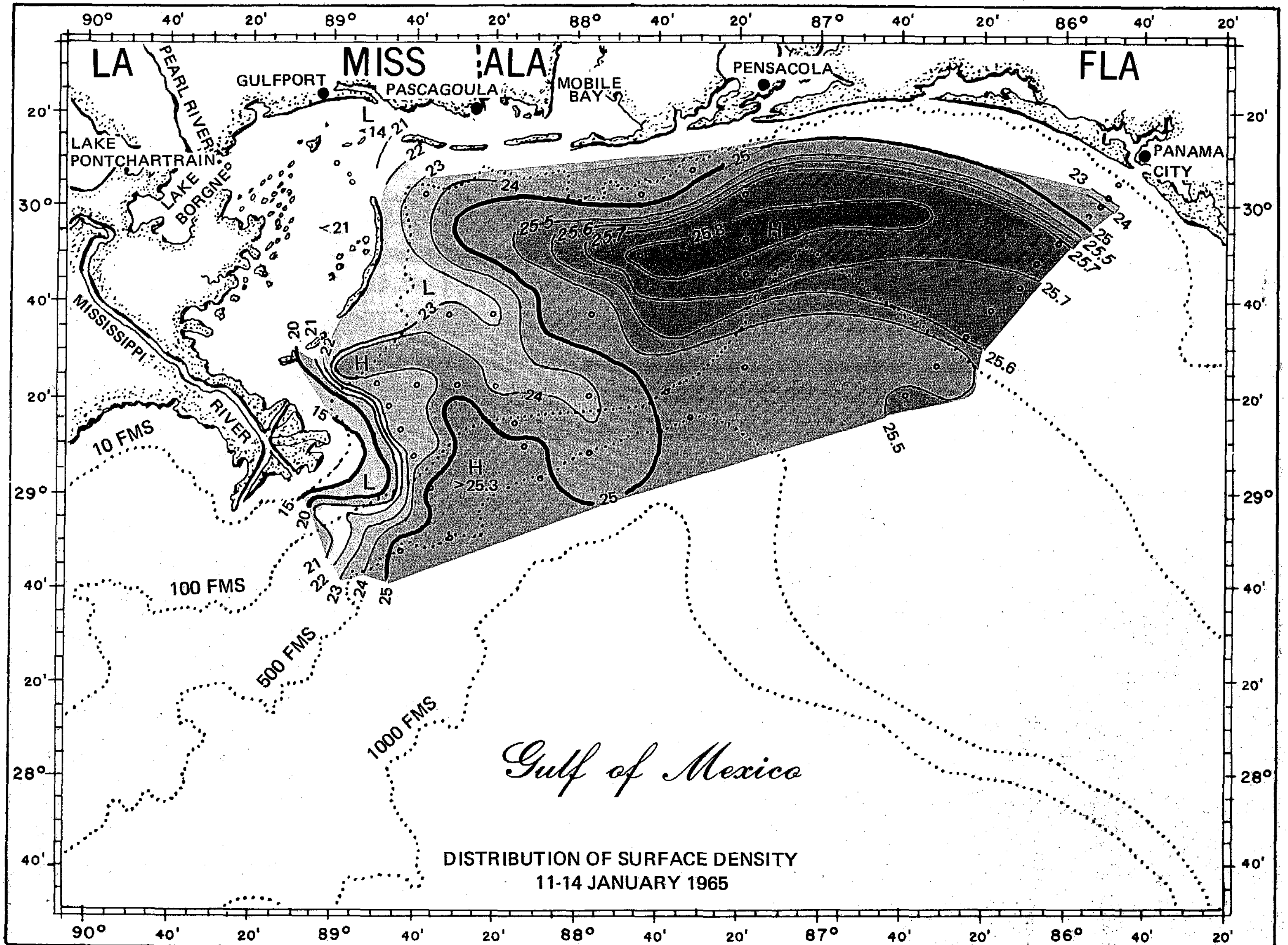


FIGURE 15. DISTRIBUTION OF SURFACE DENSITY, 11 - 14 JANUARY, 1965.

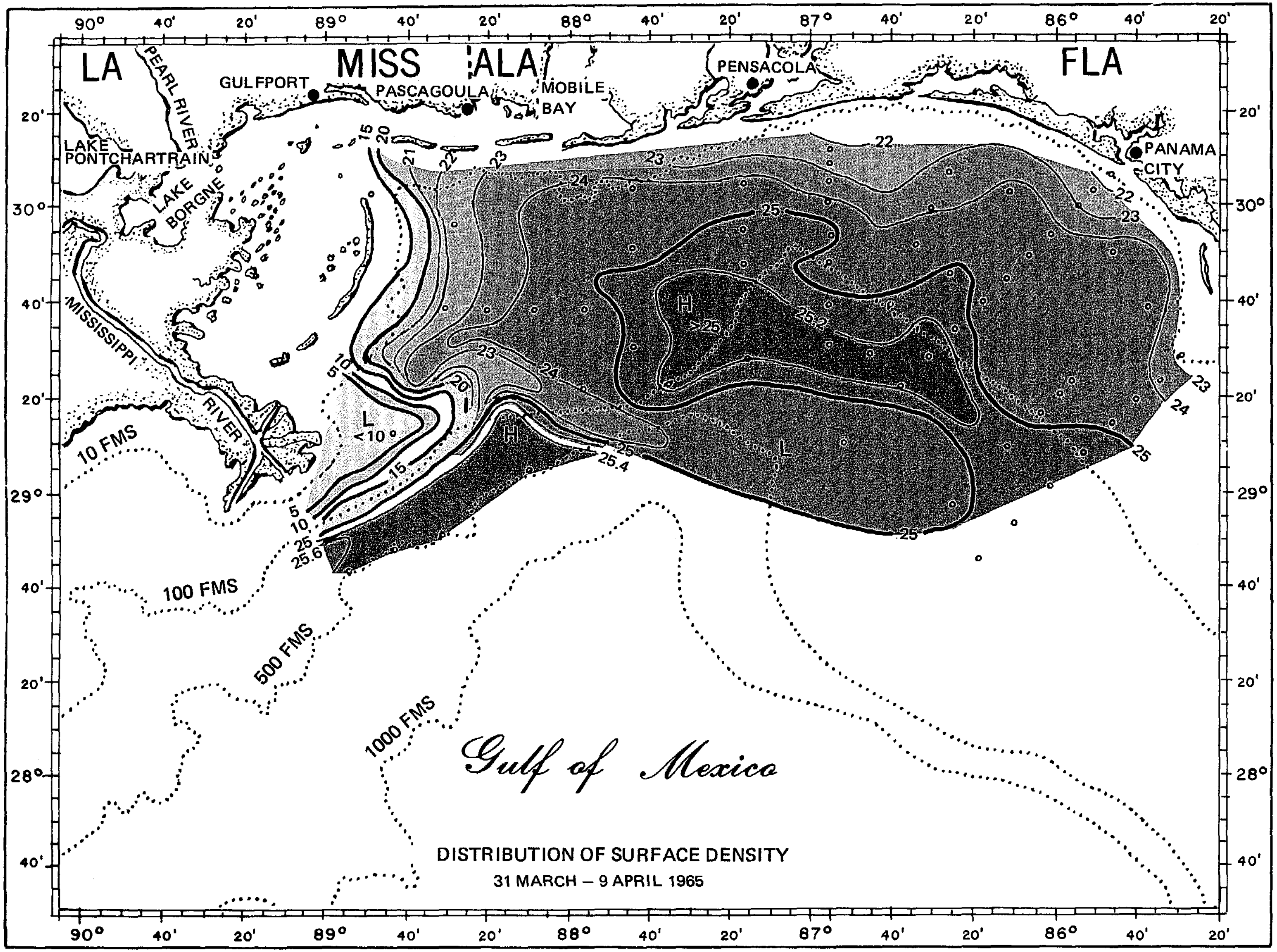


FIGURE 16. DISTRIBUTION OF SURFACE DENSITY, 31 MARCH - 9 APRIL, 1965.

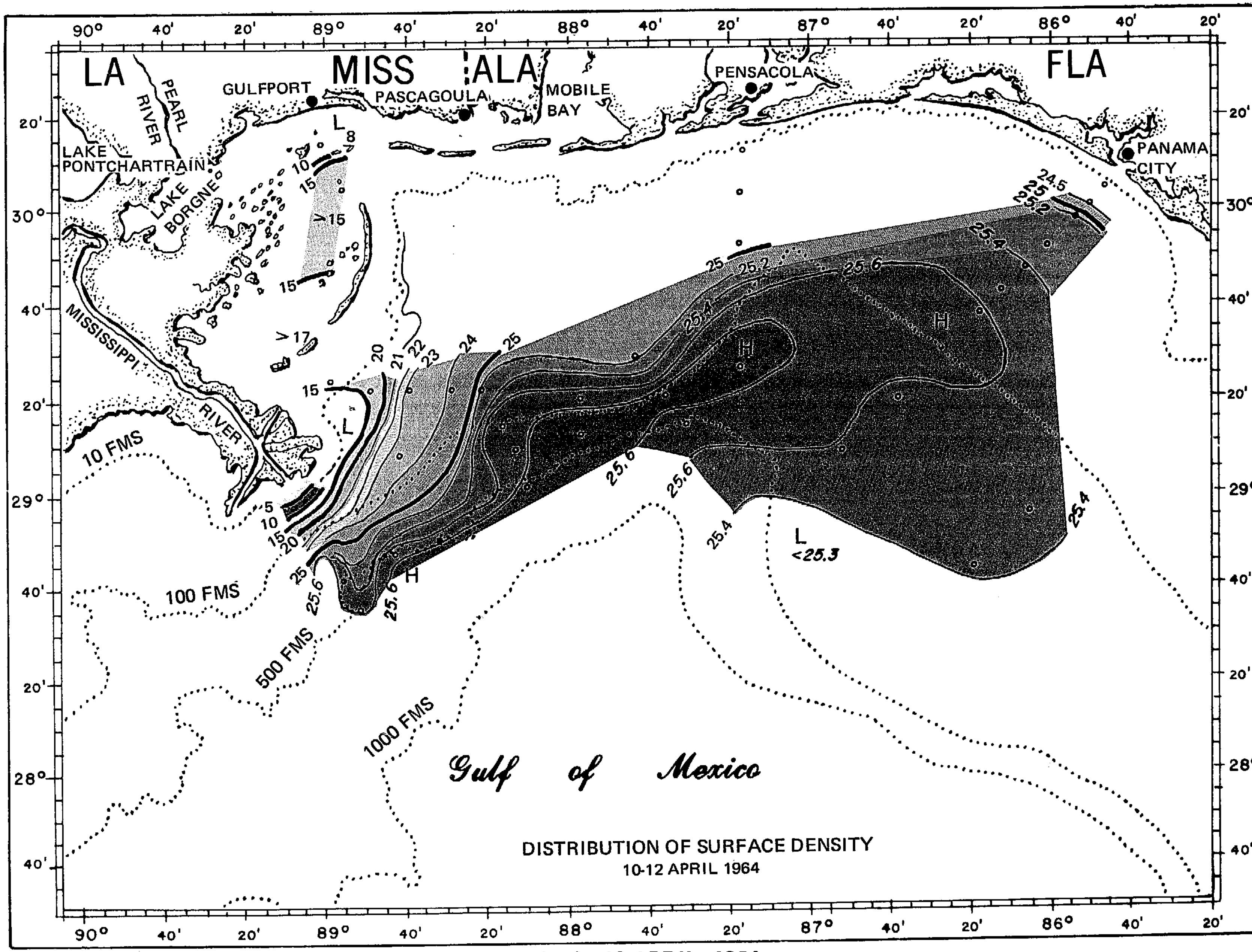


FIGURE 17. DISTRIBUTION OF SURFACE DENSITY, 10 - 12 APRIL, 1964.

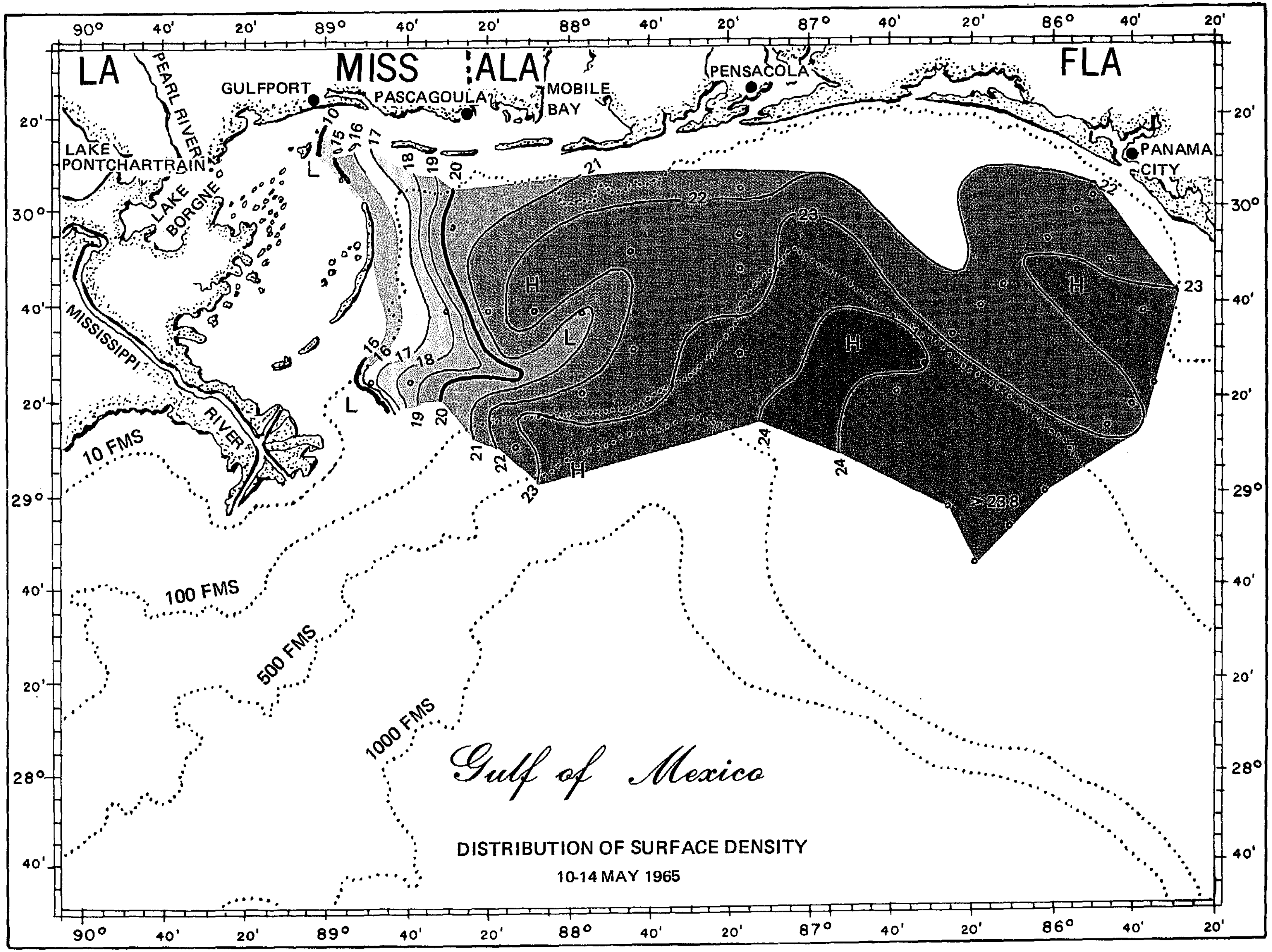


FIGURE 18. DISTRIBUTION OF SURFACE DENSITY, 10 - 14 MAY, 1965.

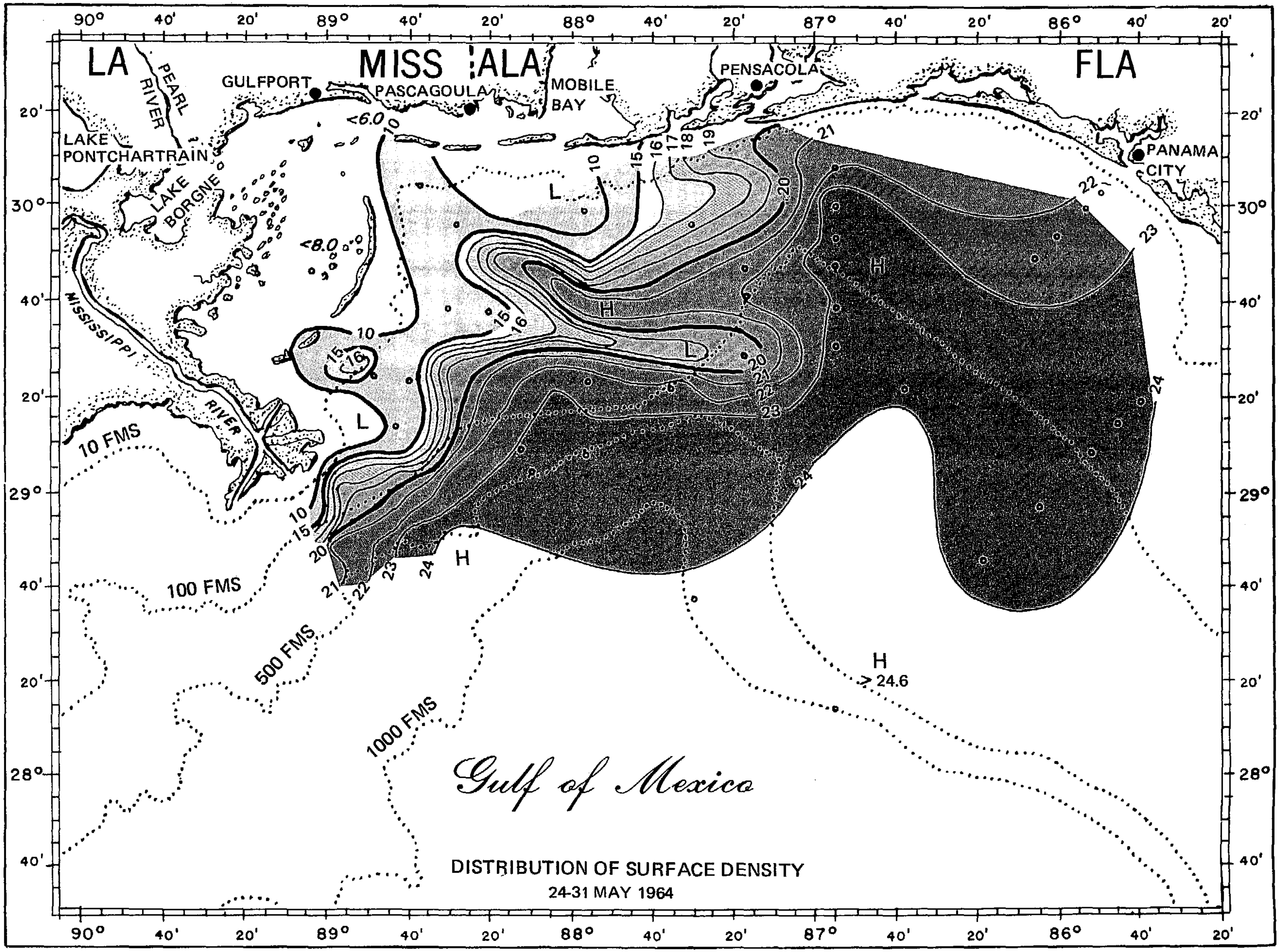


FIGURE 19. DISTRIBUTION OF SURFACE DENSITY, 24 - 31 MAY, 1964.

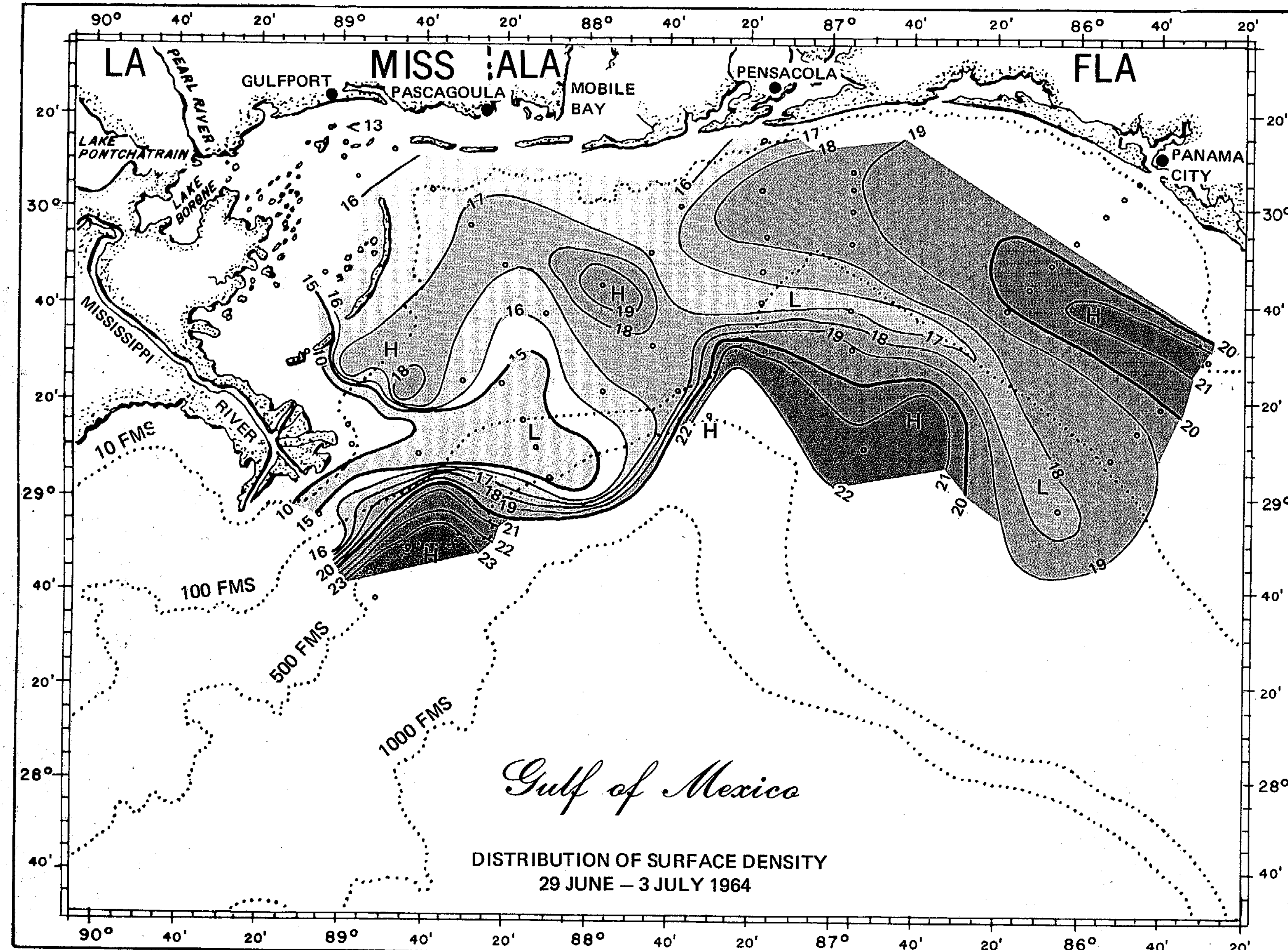


FIGURE 20. DISTRIBUTION OF SURFACE DENSITY, 29 JUNE - 3 JULY, 1964.

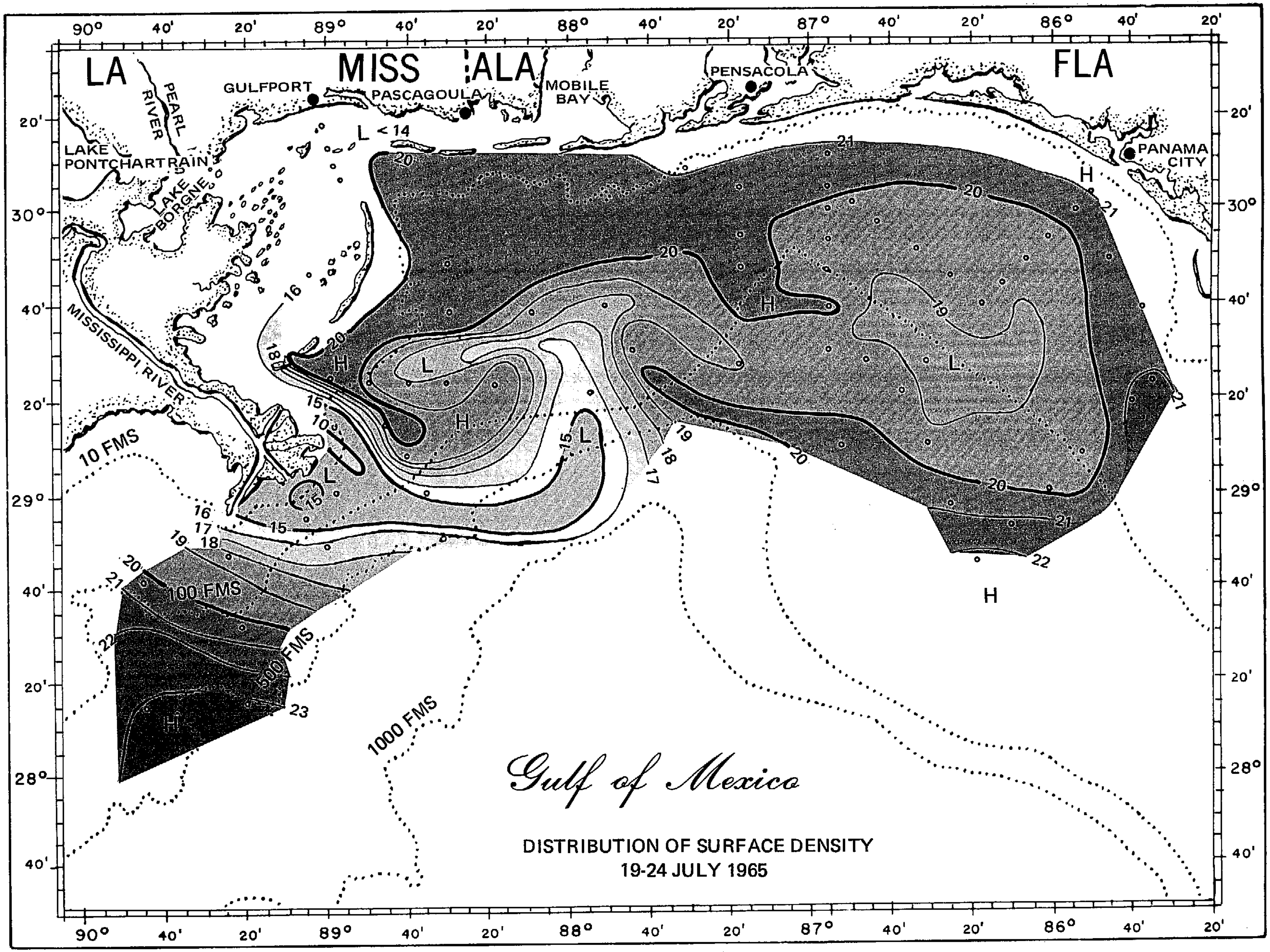


FIGURE 21. DISTRIBUTION OF SURFACE DENSITY, 19 - 24 JULY, 1965.

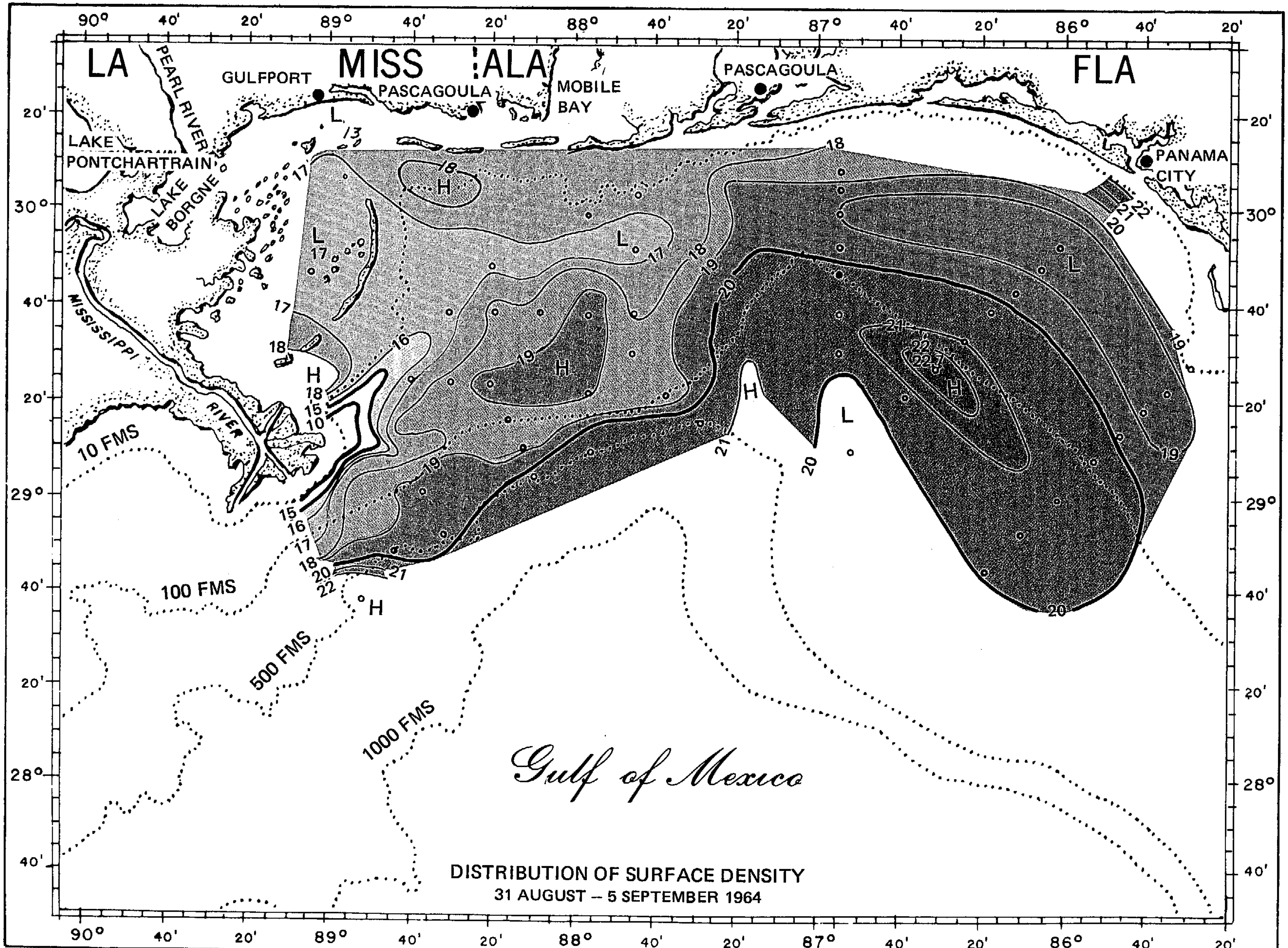


FIGURE 22. DISTRIBUTION OF SURFACE DENSITY, 31 AUGUST - 5 SEPTEMBER, 1964.

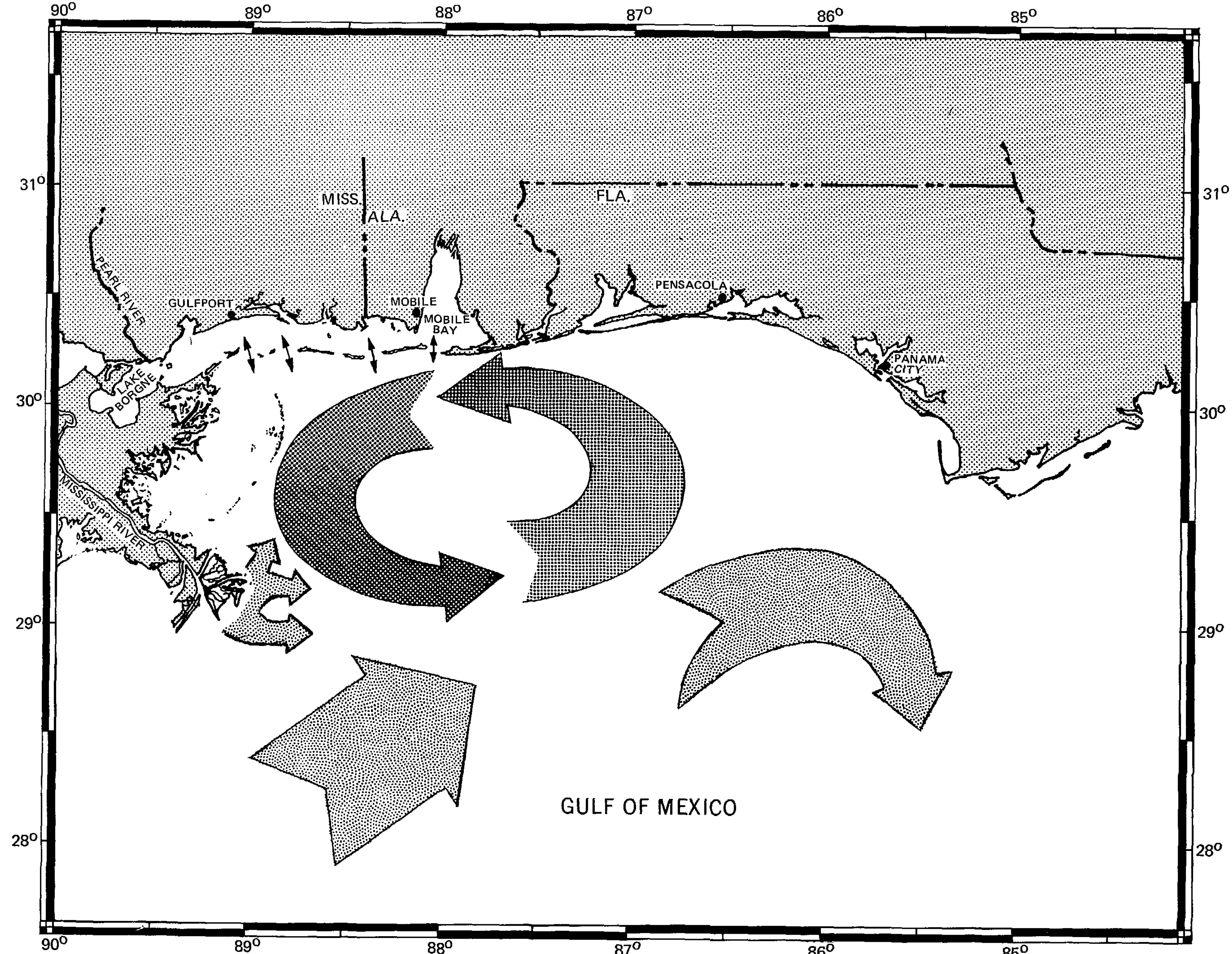


FIGURE 23. CONCEPTUAL REPRESENTATION OF CURRENTS OF SHELF AREA.

Tides of the Gulf of Mexico

The tides in the Gulf of Mexico are moderate in range but diverse in character. Across the Gulf the tide changes abruptly and assumes the following forms: diurnal, semi-diurnal, and mixed. While there is still much controversy surrounding the cause of such a complex tide regime, it is generally believed that the tides of the Gulf are cooscillating with those of the Atlantic Ocean. The tides of the Atlantic are semi-diurnal in nature, i.e., there are two highs and two lows per lunar day. These semi-diurnal tides are dominant at both the Yucatan Straits and Florida Straits (Figure 24). Progressing in a counterclockwise manner around the Gulf perimeter, the tides become mixed on the southwest Florida coast from approximately Key West to Cedar Keys. From Cedar Keys to Cape San Blas the tides are semi-diurnal again. The tides are dominantly diurnal from Cape San Blas to Vermillion Bay, Louisiana. From this point in Louisiana to Rio Grande, the tides are again mixed. The entire Gulf Coast of Mexico experiences diurnal tides.

Variations in barometric pressure and winds result in changes in sea level over short periods of time. A reduction in barometric pressure will result in a corresponding rise in sea level, and a rise in barometric pressure will be followed by a fall in sea level.

The diurnal tidal components of primary importance in the Gulf of Mexico are the components K_1 with a period of 23.93 hours and O_1 with a period of 25.84 hours. The principal semi-diurnal components are M_2 with a period of 12.42 hours and S_2 with a period of 12.00 hours.

The average tidal range in the area proposed for location of a Superport monobuoy is 1.8 feet. In the nearshore regions, tidal currents in excess of one knot have been observed during periods of tropic tides which have a large tidal range. Analytical studies of the open Gulf tides in this area to determine the phase and magnitude of the tidal currents have not been undertaken.

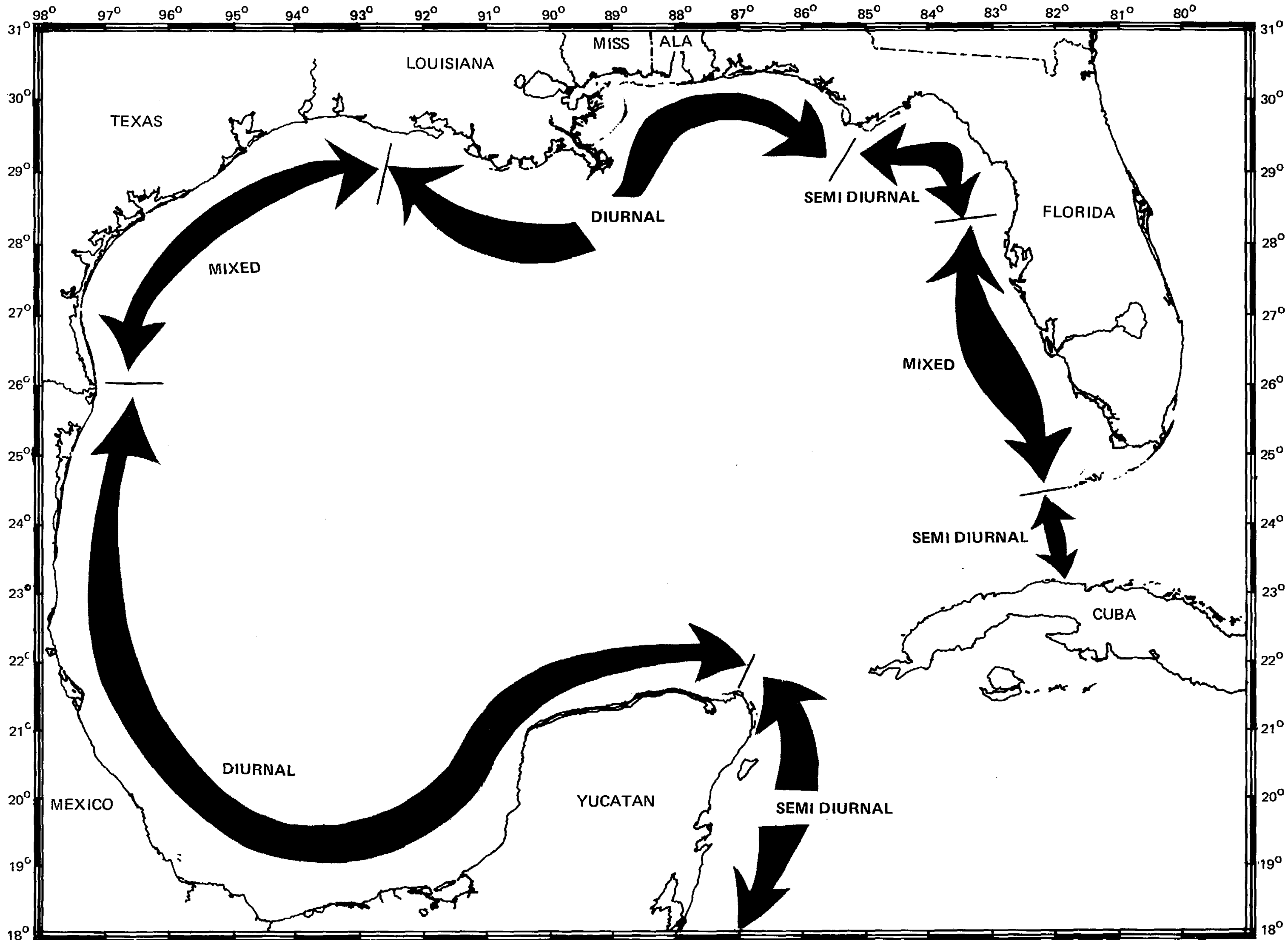


FIGURE 24. GULF OF MEXICO TIDAL REGIMES.

Winds and Wind-Driven Circulation

Wind-driven circulation is produced by the drag of the wind passing over the water. This wind stress, applied at the sea surface and affecting the subsurface waters through frictional coupling, drives the surface waters at a 45-degree angle to the wind vector in the Northern Hemisphere. Due to this direct effect upon the water circulation, it appears necessary to discuss the wind fields of the proposed site area at this point.

The wind statistics used in this report were computed from 20 years of continuous records collected at Keesler Air Force Base, Biloxi, Mississippi. The wind gauge, located at 30°24'N, 88°55'W at a vane elevation of 36 feet, is approximately 32 statute miles north-northwest of the proposed site. Wind data from this particular site were selected for utilization in this assessment for three reasons: the records provide a sufficiently long time series; the location of the gauge is the closest and most reliable weather station to the proposed site; and the wind data from ship logs are especially scanty in this area.

The length of the vectors depicted in Figures 25-37 represents the percent of time the wind blows in a particular direction. The corresponding table located in the lower right corner of the illustration provides the wind speed, for 16 directions and calm, as a percent of time for a particular range in speed. Totals of the percentages appear in the bottom line of the table. For example, a north wind is depicted as a vector pointing south with the percent of time it was encountered corresponding to the magnitude of the vector. The wind speeds associated with this north wind will be found in the table under the proper direction designation, N. The appearance of zeros in a tenths position in the table implies that there was a small percentage of time when the wind attained such speeds.

The winds of January (Figure 25) are primarily from the north and northeast with an average speed of 7-10 knots and on rare occasions, less than 0.1 percent of the time, reaching a maximum of 28-33 knots. Overall, the source of the winds during the month is dominately from the eastern sector from 0° (north) to 180° (south). Considering all winds, 38 percent of the time the wind speed ranges between 7-10 knots. Winds exceed 21 knots less than 1 percent of the time. Over 11 percent of the time there are no winds.

During February (Figure 26) the distribution of wind directions and wind speeds are similar to January with the winds primarily from the eastern sector. Wind speed, for all winds, ranges from 7-10 knots over 40 percent of the time and less than 17 knots over 96 percent of the time. There is no wind during 10.5 percent of the time.

During March (Figure 27) the wind pattern shifts so that the winds are primarily from north-northeast and south-southeast. Over 41 percent of the time the winds are between 7 and 10 knots, and less than 17 knots over 96 percent of the time. Winds are nonexistent over 9 percent of the time.

In April (Figure 28) the winds are predominantly from the southeast quadrant. Winds attain or exceed 17 knots less than 3 percent of the time.

The dominant winds have an origin between east-southeast and south-southwest during May (Figure 29). The wind speeds diminish significantly from April with winds less than 17 knots occurring 98.7 percent of the time and winds less than 11 knots prevailing 82.9 percent of the time. Included in these two percentages are the periods of calm (no wind) which amounts to 11.1 percent of the time.

There is a slight shift in dominant wind direction to the southwest during June (Figure 30) from May with an additional decrease in wind speeds. Winds attain or exceed 17 knots less than 1 percent of the time. Over 88 percent of the time, the winds, including the 12.5 percent designated as calm, possess speeds less than 11 knots.

The primary source of the winds shifts to the southwest quadrant during July (Figure 31). The winds continue to diminish compared to the previous month as reflected by the increase in the percent of time denoted as calm. Winds attain or exceed a speed of 17 knots less than 1 percent of the time. The winds are less than 10 knots almost 93 percent of the time.

In August (Figure 32) the winds diminish to their lowest point for the year. The direction of the wind during this month originates primarily in the northeast and southwest quadrants with the latter occurring more frequently. Calm prevails almost 17 percent of the time.

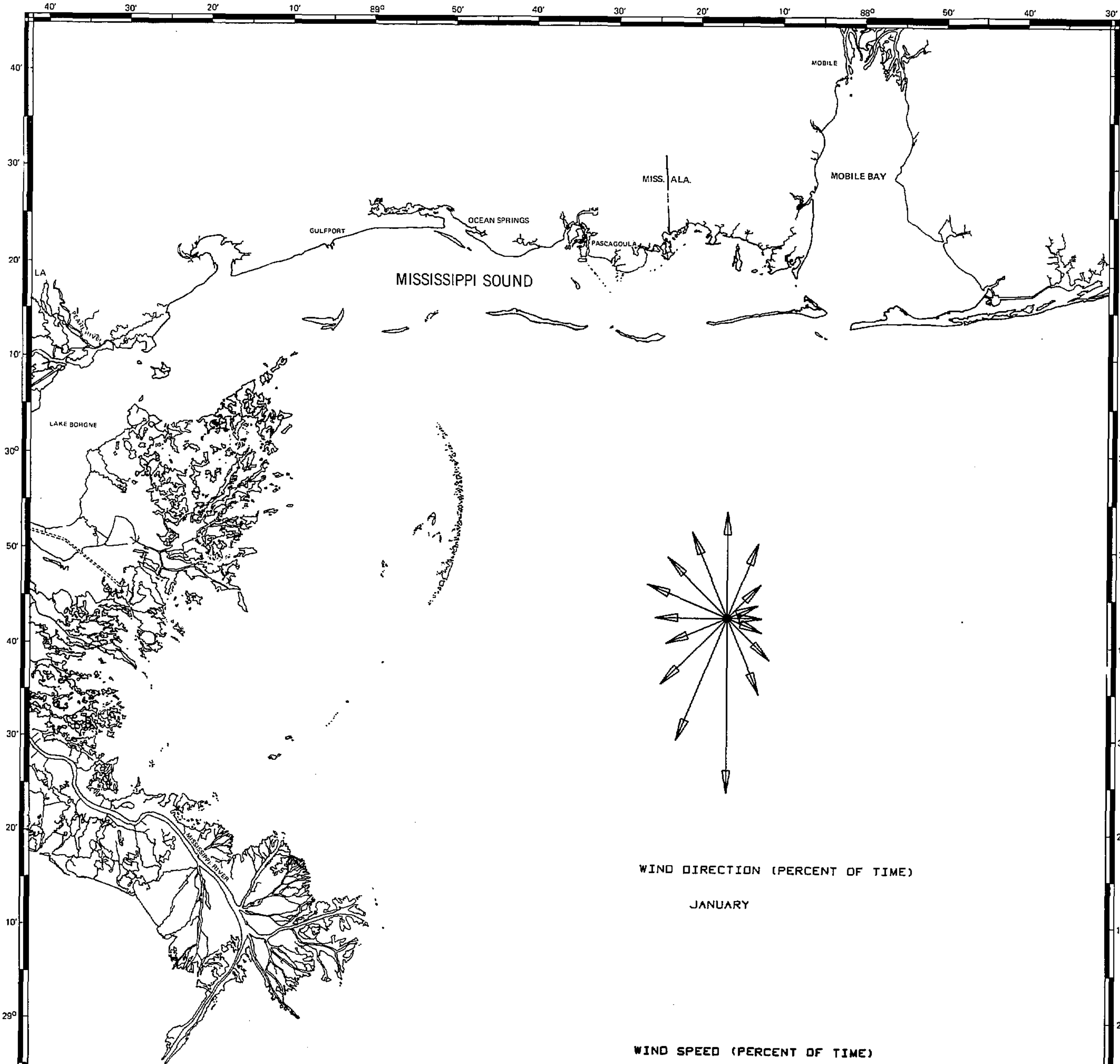
The winds are predominantly from the northeast quadrant during September (Figure 33). Winds from the western sector are minimal over the month.

There is a shift in the winds to a more northerly course during October (Figure 34) with the major source of the winds coming from the northeast quadrant. The wind speeds are less than 11 knots more than 87 percent of the time.

Even though the primary source of November winds (Figure 35) remains from the northeast quadrant, there is a significant percentage of time when the winds are from the southeast. The winds are below 11 knots more than 82 percent of the time during November. The winds have speeds in excess of 17 knots less than 3 percent of the time.

The pattern of winds for December (Figure 36) is very similar to that of the previous month. Winds with speeds less than 11 knots still account for over 82 percent of the time.

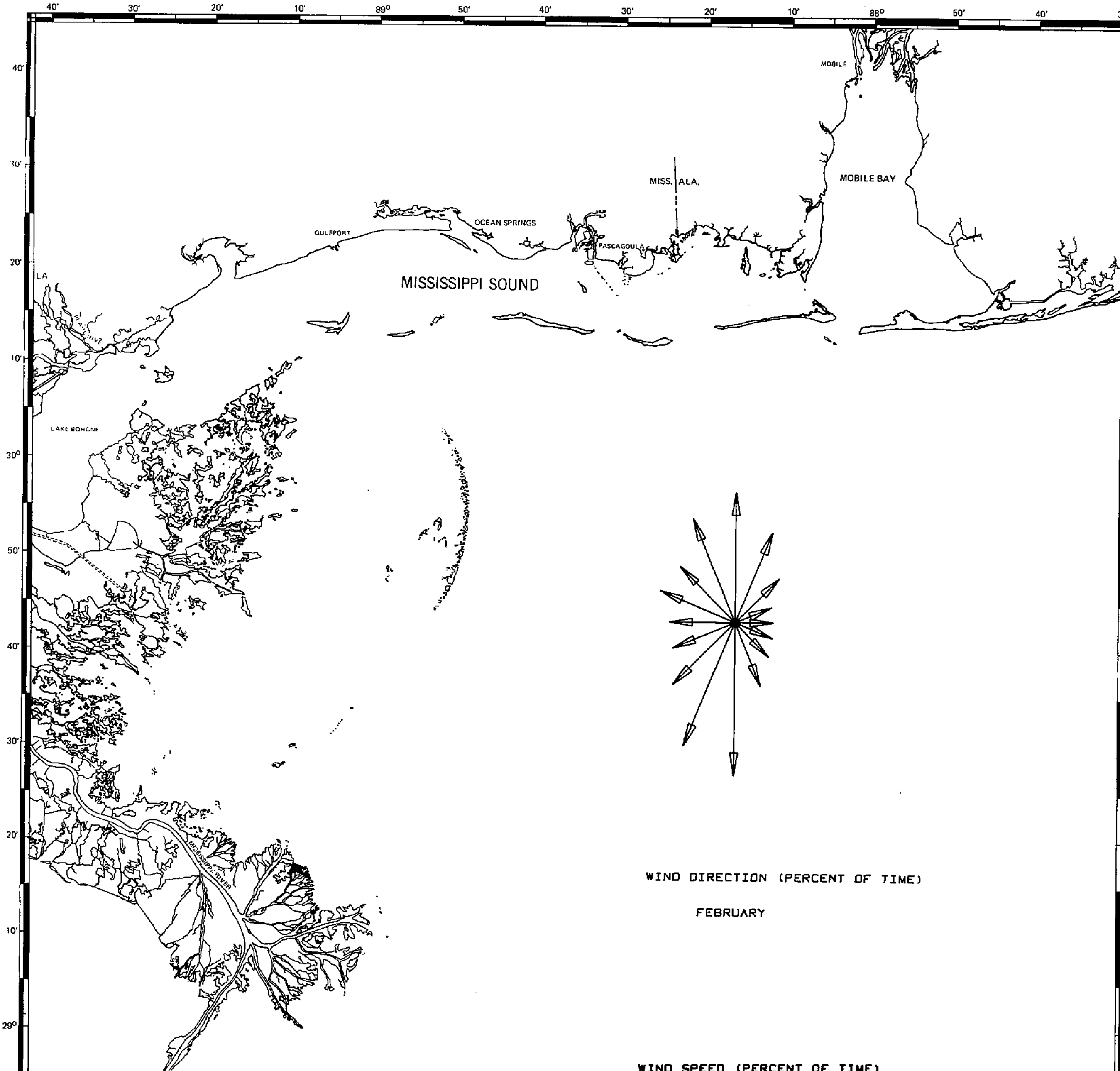
Figure 37 is a composite depiction of wind information for all months. Winds with sources in the eastern sector clearly dominate the wind regime. It is of particular interest to note that the percentage of time when calm or winds to 3 knots prevail is 13.8. Winds less than 7 knots account for over 32 percent of the time; winds less than 11 knots for more than 72 percent; winds less than 17 knots, more than 94 percent. The time thus attributable to winds of 17 knots or greater is less than 6 percent.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	1.0	2.3	4.6	3.3	.6	.1	.0				
NNE	.8	2.1	3.6	2.2	.5	.1					
NE	.7	1.7	2.9	1.0	.2	.1					
ENE	.7	1.6	1.9	.4	.0						
E	.6	1.4	2.4	.6	.0						
ESE	.4	.9	2.9	1.7	.1						
SE	.3	1.0	2.8	1.6	.2						
SSE	.4	1.5	3.0	1.4	.1	.0					
S	.7	2.1	3.2	1.2	.1	.0					
SSW	.4	1.5	2.6	1.0	.1	.0					
SW	.3	1.1	1.5	.3	.1						
WSW	.2	.5	1.0	.4	.1	.0					
W	.4	.7	.9	.3	.0						
WNW	.3	.6	1.0	.5	.2	.0	.0				
NW	.6	1.0	1.3	.9	.3	.0					
NNW	.5	1.1	2.3	1.3	.4	.1	.0				
CALM									TOTAL CALM % = 11.2		
	8.2	21.1	38.0	18.1	3.0	.5	.0				

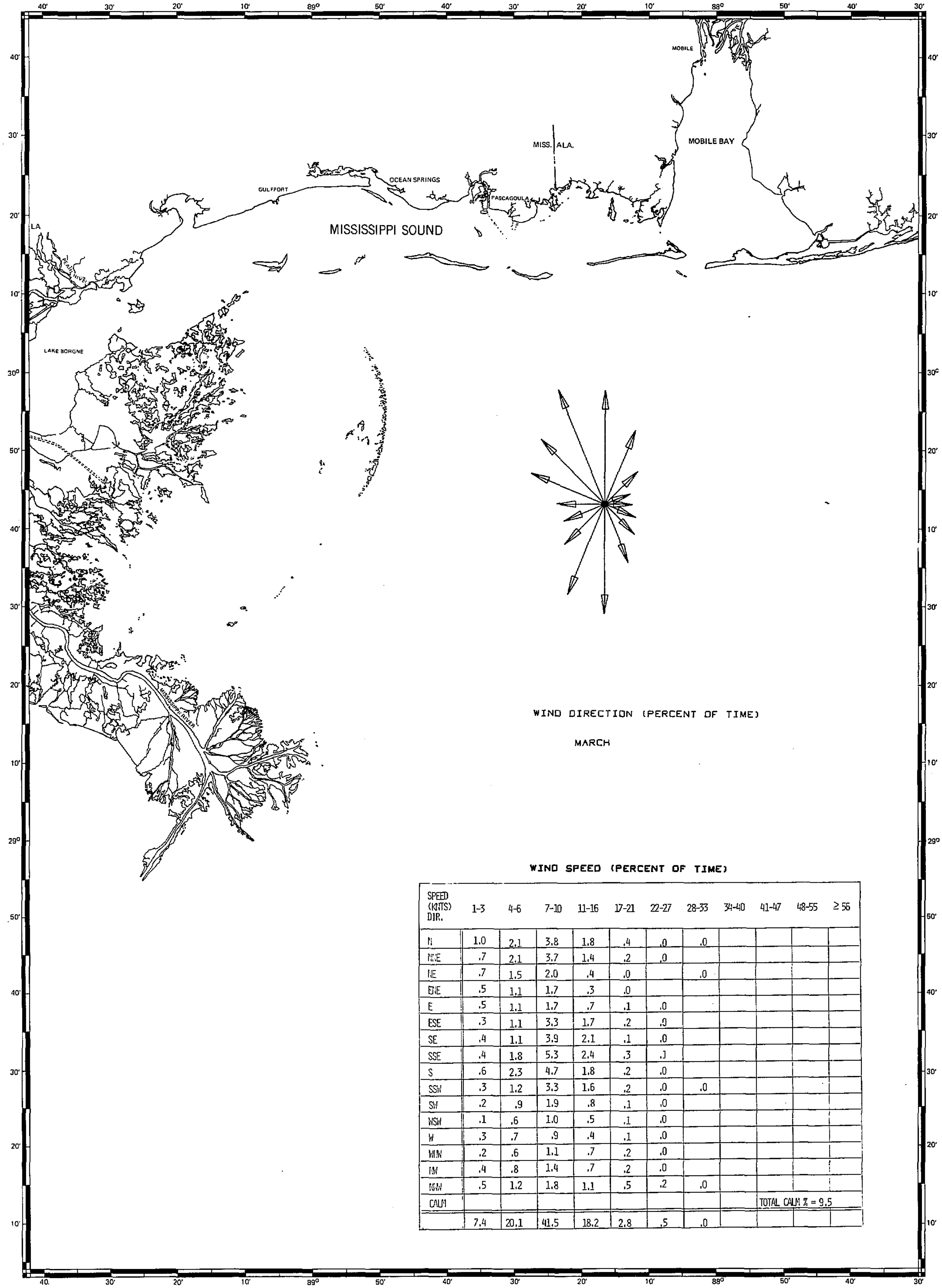
FIGURE 25. WIND DIRECTION AND SPEED, JANUARY.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	.7	2.3	4.4	2.3	.6	.1					
NNE	.8	2.0	4.4	1.5	.3	.1					
NE	.8	1.9	2.7	.5	.0	.0					
ENE	.5	1.6	2.1	.4	.0	.0					
E	.5	1.3	1.9	.6	.1	.0					
ESE	.3	.9	2.2	1.9	.2	.0					
SE	.3	1.0	2.5	1.4	.1	.0					
SSE	.4	1.7	4.1	1.4	.2	.0					
S	.6	2.0	4.8	1.3	.1	.0	.0				
SSW	.5	1.6	3.2	1.2	.1	.0	.0				
SW	.4	1.0	1.8	1.0	.1						
WSW	.2	.8	1.0	.6	.1	.0					
W	.3	.8	1.0	.3	.0	.0					
WNW	.2	.7	1.1	.6	.1	.0	.0				
NW	.4	.7	1.2	.8	.2	.0					
NNW	.4	1.1	1.5	1.2	.4	.1	.0				
CALM									TOTAL CALM % =10.5		
	7.4	21.4	40.2	17.2	2.8	.4	.0				

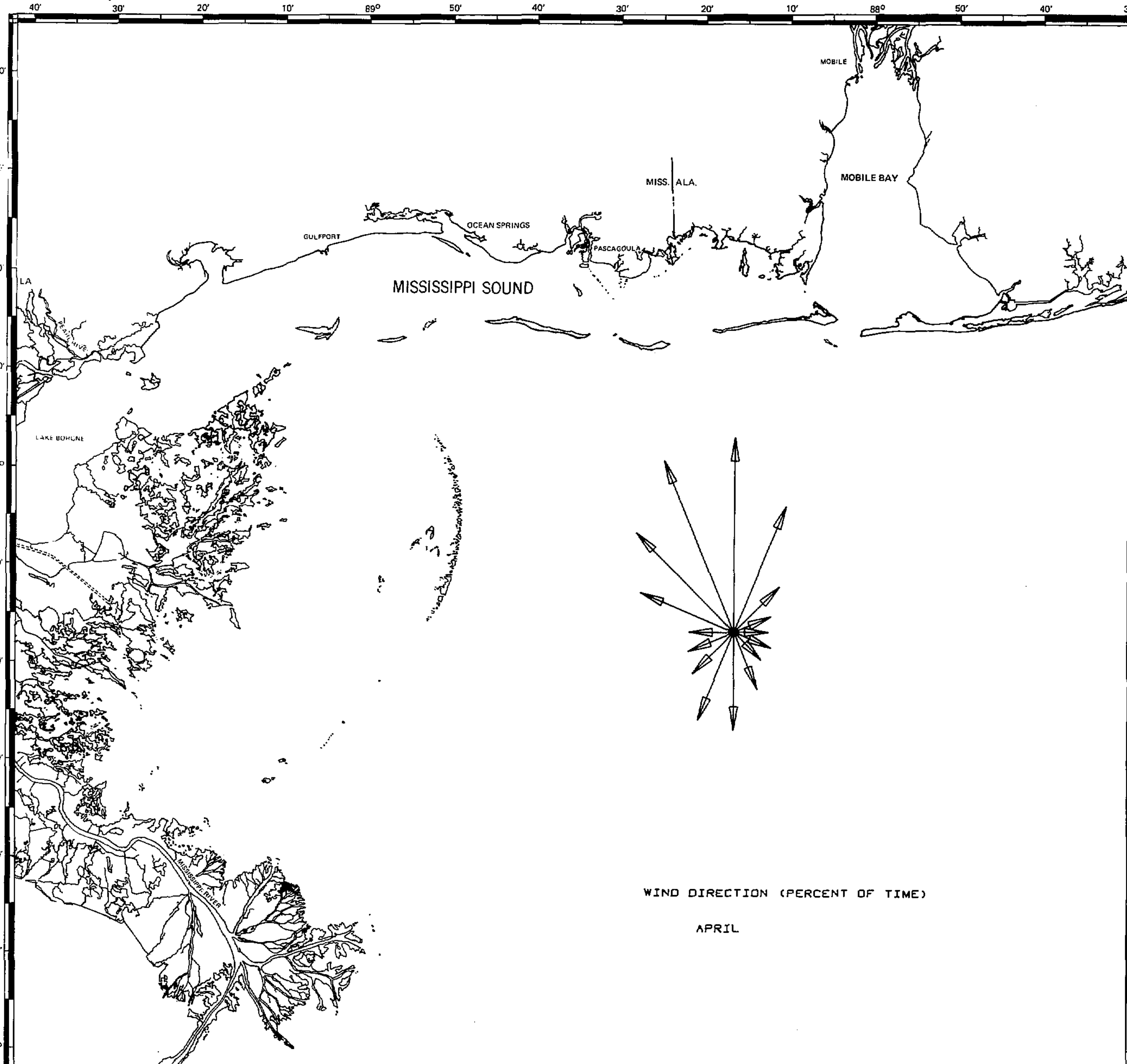
FIGURE 26. WIND DIRECTION AND SPEED, FEBRUARY.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	1.0	2.1	3.8	1.8	.4	.0	.0				
NNE	.7	2.1	3.7	1.4	.2	.0					
NE	.7	1.5	2.0	.4	.0		.0				
ENE	.5	1.1	1.7	.3	.0						
E	.5	1.1	1.7	.7	.1	.0					
ESE	.3	1.1	3.3	1.7	.2	.0					
SE	.4	1.1	3.9	2.1	.1	.0					
SSE	.4	1.8	5.3	2.4	.3	.1					
S	.6	2.3	4.7	1.8	.2	.0					
SSW	.3	1.2	3.3	1.6	.2	.0	.0				
SW	.2	.9	1.9	.8	.1	.0					
WSW	.1	.6	1.0	.5	.1	.0					
W	.3	.7	.9	.4	.1	.0					
WNW	.2	.6	1.1	.7	.2	.0					
NW	.4	.8	1.4	.7	.2	.0					
NNW	.5	1.2	1.8	1.1	.5	.2	.0				
CALM									TOTAL CALM % = 9.5		
	7.4	20.1	41.5	18.2	2.8	.5	.0				

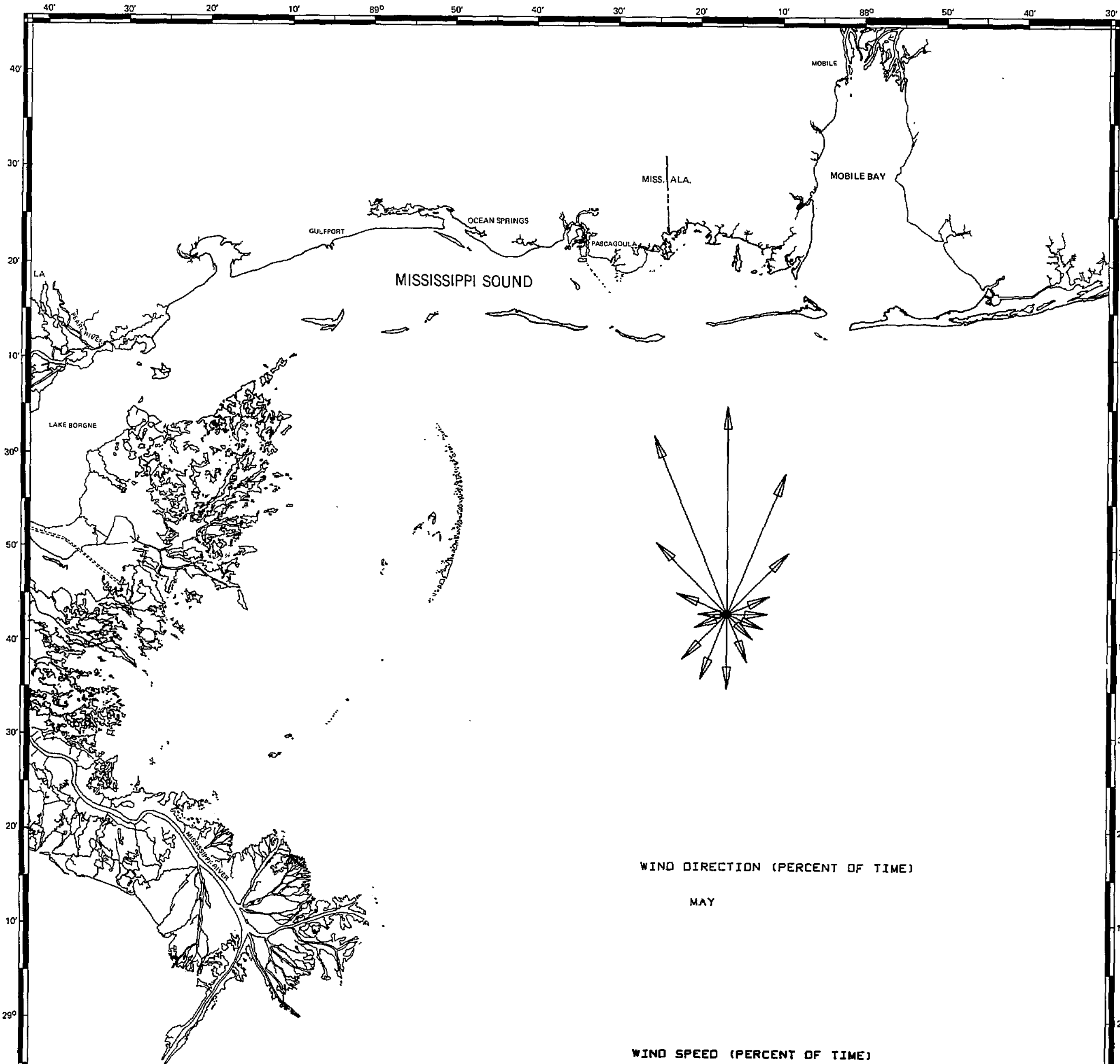
FIGURE 27. WIND DIRECTION AND SPEED, MARCH.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	.8	1.6	2.6	1.1	.2	.0					
NNE	.9	1.6	2.7	.8	.2	.1	.0				
NE	.9	1.2	1.5	.3	.0						
ENE	.6	1.2	1.3	.2	.0						
E	.5	.9	1.2	.4	.0						
ESE	.3	1.0	3.0	2.3	.2	.0	.0				
SE	.4	1.4	4.4	2.9	.2	.0					
SSE	.7	2.1	6.3	3.1	.2	.1	.0				
S	.5	2.5	7.0	2.9	.1	.1					
SSW	.4	1.5	4.3	2.6	.2	.0	.0				
SW	.3	.7	2.2	1.1	.1	.0					
WSW	.2	.6	1.3	.6	.1	.0					
W	.3	.7	1.0	.3	.0						
WNW	.4	.7	1.1	.5	.1						
NW	.4	.8	.9	.5	.0	.0					
NNW	.4	1.0	1.8	.8	.1	.0					
CALM									TOTAL CALM % = 7.7		
	8.0	19.4	42.5	20.1	1.9	.4	.0				

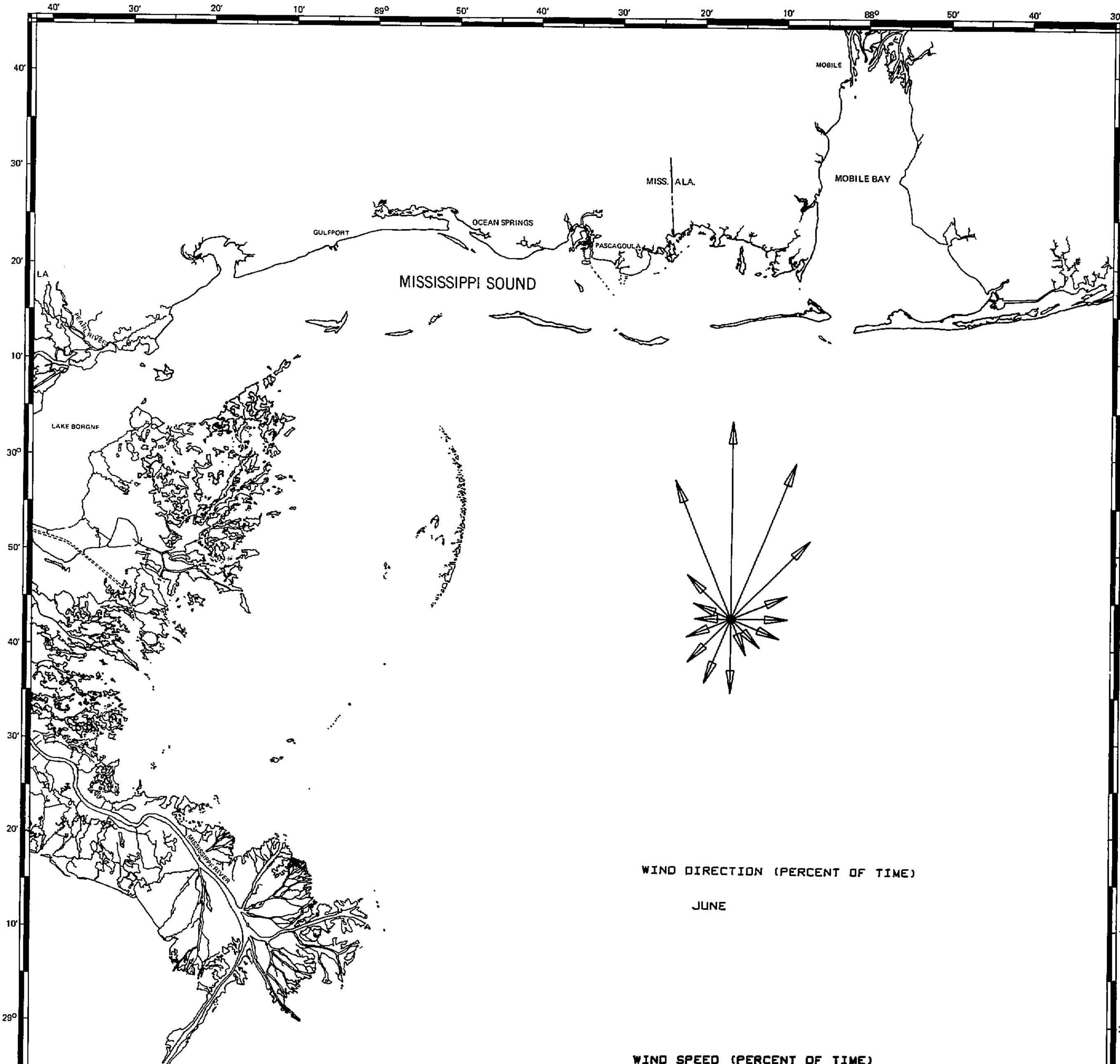
FIGURE 28. WIND DIRECTION AND SPEED, APRIL.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	1.1	1.8	1.7	.6	.1						
NNE	1.1	1.6	1.8	.3	.0						
NE	1.2	1.7	1.3	.2	.0						
ENE	.6	.8	.9	.1							
E	.3	.6	.8	.3	.0						
ESE	.2	.6	1.8	1.2	.1						
SE	.4	1.0	3.4	2.1	.1	.0					
SSE	.7	2.2	6.5	3.6	.3	.1					
S	.7	2.9	7.7	2.8	.4	.0	.0				
SSW	.4	1.9	5.9	2.3	.1	.0					
SW	.4	1.4	3.1	1.0	.1						
WSW	.4	1.0	1.4	.4	.0	.0					
W	.6	1.1	1.0	.2	.0						
WNW	.5	.9	1.0	.3	.0	.0					
NW	.6	.9	.8	.1	.0						
NNW	.7	1.1	1.3	.4	.1	.0					
CALM									TOTAL CALM % = 11.1		
	9.9	21.7	40.2	15.8	1.3	.1	.0				

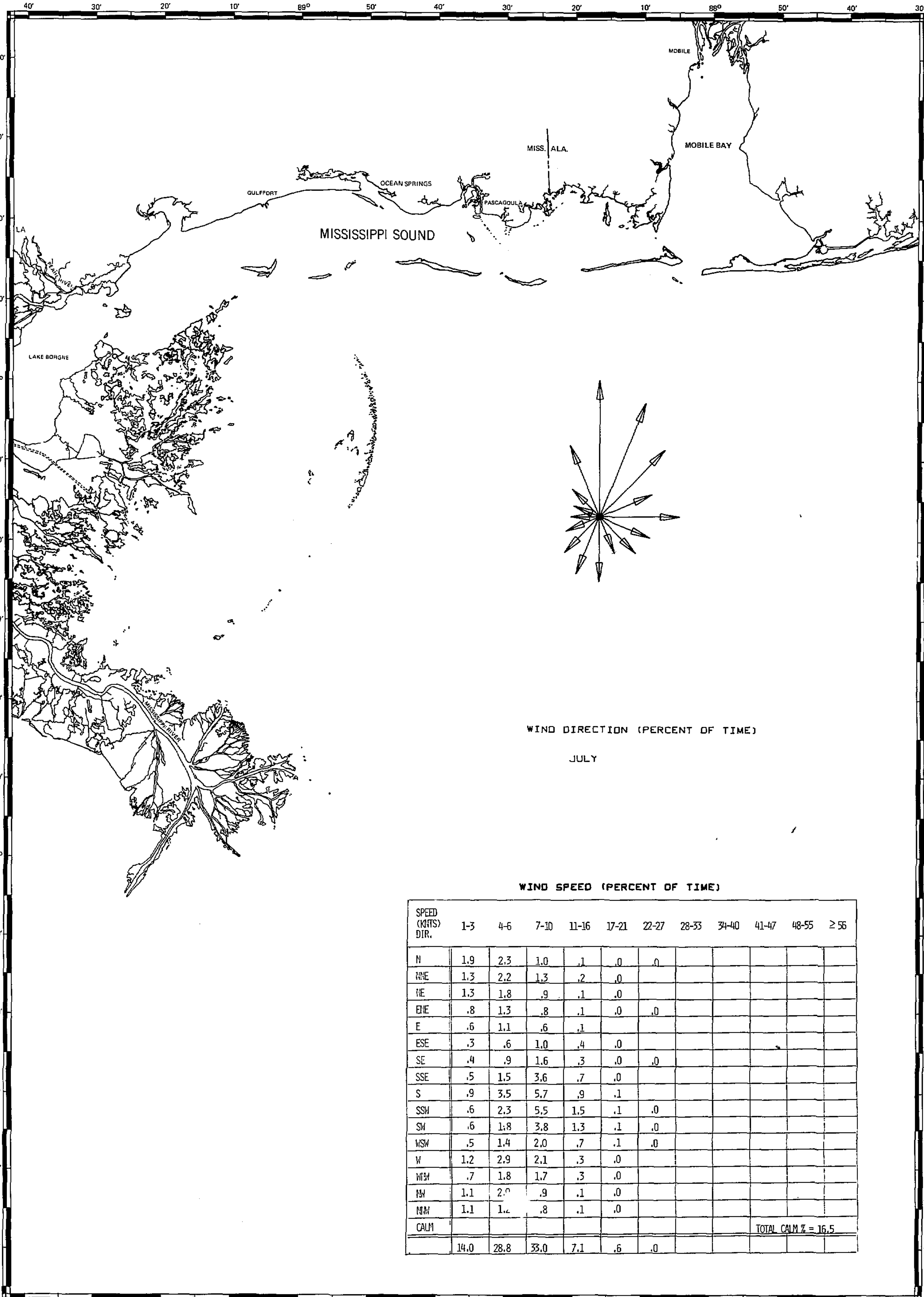
FIGURE 29. WIND DIRECTION AND SPEED, MAY.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	1.6	1.9	1.4	.2	.0						
NNE	1.3	1.9	1.4	.2	.0	.0					
NE	1.1	2.0	1.1	.1	.0						
ENE	.7	1.5	1.0	.1	.0	.0					
E	.5	1.0	.8	.2	.0						
ESE	.3	.7	1.2	.6	.0	.0	.0				
SE	.3	.9	2.2	.8	.1	.0					
SSE	.5	2.2	5.6	1.7	.2	.0					
S	.8	3.2	7.7	1.8	.1	.0					
SSW	.5	2.2	6.4	2.3	.2	.0					
SW	.7	1.8	3.8	1.3	.1	.0					
WSW	.5	1.3	1.9	.5	.0	.0					
W	1.0	1.6	1.1	.2							
WNW	.7	1.3	1.3	.2	.0	.0					
NW	.9	1.1	.7	.1			.0				
NNW	.7	1.1	.7	.1	.0						
CALM									TOTAL CALM % = 12.5		
	12.2	25.7	38.2	10.5	.8	.1	.0				

FIGURE 30. WIND DIRECTION AND SPEED, JUNE.



WIND SPEED (PERCENT OF TIME)

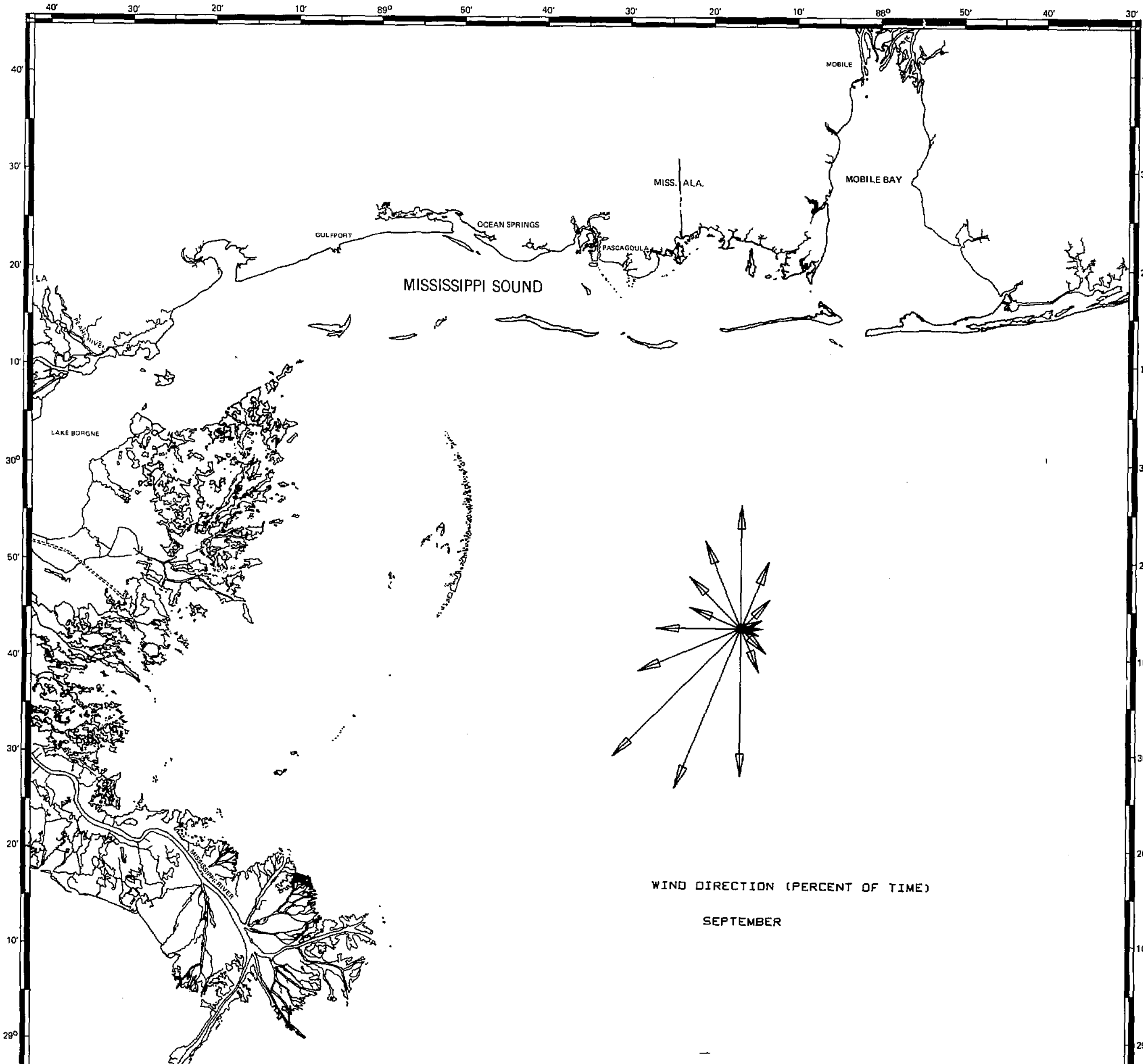
SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	1.9	2.3	1.0	.1	.0	.0					
NNE	1.3	2.2	1.3	.2	.0						
NE	1.3	1.8	.9	.1	.0						
ENE	.8	1.3	.8	.1	.0	.0					
E	.6	1.1	.6	.1							
ESE	.3	.6	1.0	.4	.0						
SE	.4	.9	1.6	.3	.0	.0					
SSE	.5	1.5	3.6	.7	.0						
S	.9	3.5	5.7	.9	.1						
SSW	.6	2.3	5.5	1.5	.1	.0					
SW	.6	1.8	3.8	1.3	.1	.0					
WSW	.5	1.4	2.0	.7	.1	.0					
W	1.2	2.9	2.1	.3	.0						
WNW	.7	1.8	1.7	.3	.0						
NW	1.1	[illegible]	.9	.1	.0						
NNW	1.1	[illegible]	.8	.1	.0						
CALM									TOTAL CALM % = 16.5		
	14.0	28.8	33.0	7.1	.6	.0					

FIGURE 31. WIND DIRECTION AND SPEED, JULY.

WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	2.5	3.0	1.7	.2	.0						
NNE	1.7	2.7	1.8	.2	.0		.0				
NE	1.7	2.7	1.9	.1	.0						
ENE	.7	1.7	1.6	.3	.0	.0					
E	.7	1.3	1.0	.2	.0						
ESE	.3	.7	1.0	.2	.0						
SE	.4	1.0	1.7	.5	.0	.0					
SSE	.4	1.7	3.0	.6	.1	.0	.0				
S	1.0	3.1	4.7	1.0	.0						
SSW	.6	1.9	4.7	1.3	.1		.0				
SW	.5	1.4	3.1	.9	.0						
WSW	.4	1.3	1.4	.3	.0	.0					
W	1.1	2.0	1.4	.2	.0						
WNW	.8	1.4	1.3	.3	.0						
NW	1.0	1.4	1.1	.1					.0		
NNW	1.0	1.4	1.0	.2	.0			.0			
CALM									TOTAL CALM % = 16.8		
	14.8	28.8	32.5	6.6	.4	.0	.0	.0	.0		

FIGURE 32. WIND DIRECTION AND SPEED, AUGUST.



WIND SPEED (PERCENT OF TIME)

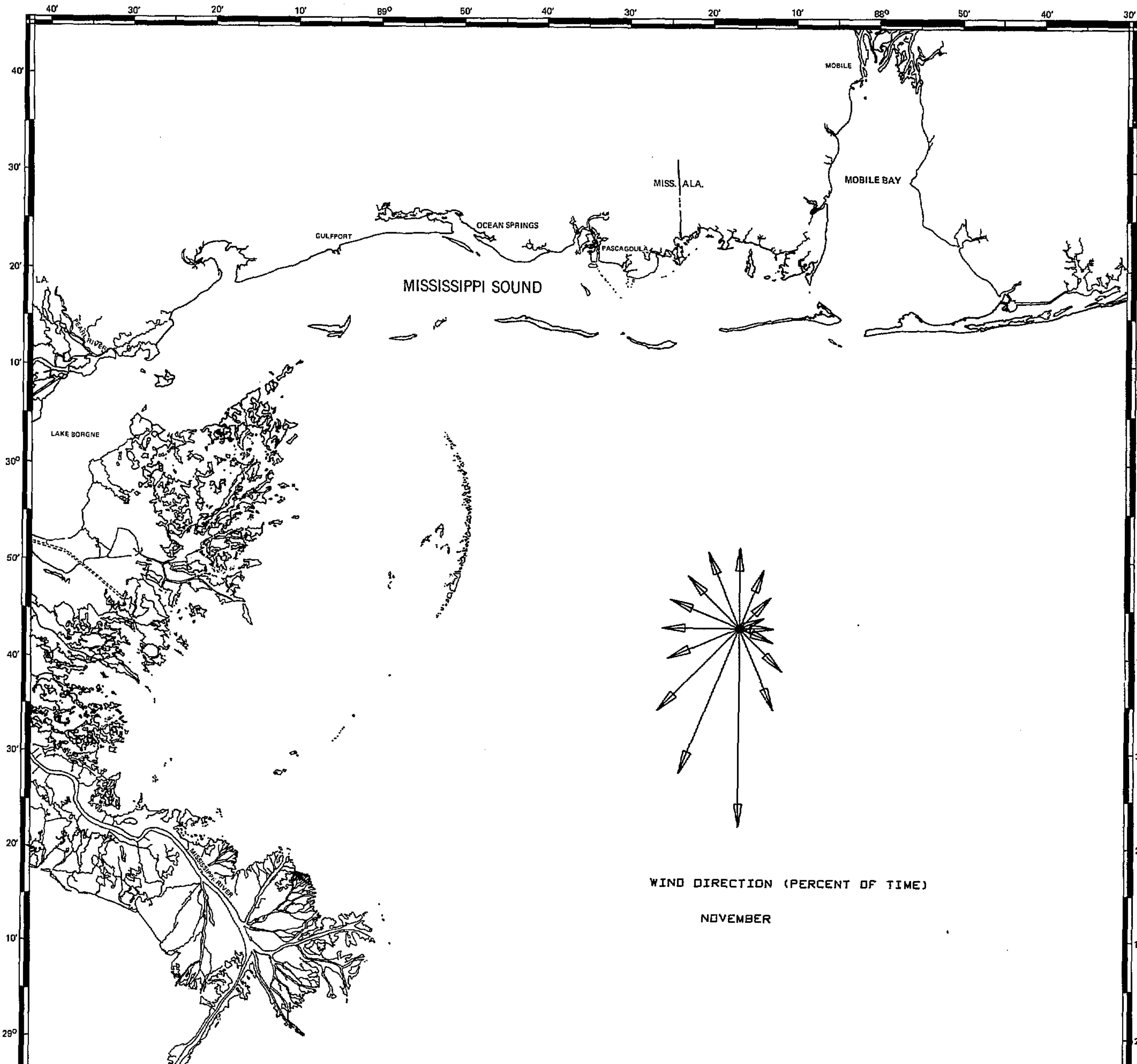
SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	2.1	3.8	3.1	.9	.1	.0					
NNE	1.4	3.6	4.9	1.5	.2	.0	.0	.0			
NE	1.5	4.5	4.8	1.2	.2	.0	.0		.0	.0	
ENE	.7	2.2	3.5	1.1	.1	.0	.0	.0			
E	.7	1.8	2.6	.8	.0	.0	.0				
ESE	.2	.9	1.8	.8	.1	.0	.0				
SE	.3	1.2	2.3	1.0	.1	.0	.0	.0			
SSE	.5	1.5	3.2	1.1	.1	.0	.0				
S	.8	2.5	3.9	1.0	.1	.0	.0				
SSW	.3	1.1	2.6	.8	.0	.0	.0		.0		
SW	.5	.7	1.2	.4	.0						
WSW	.2	.3	.6	.2	.0	.0					
W	.4	.7	.4	.1	.0	.0					
WNW	.3	.5	.4	.1	.0						
NW	.7	.9	.7	.1	.0	.0					
NNW	.6	1.1	1.1	.4	.1	.0	.0				
CALM									TOTAL CALM % = 11.4		
	11.2	27.2	37.1	11.4	1.2	.3	.1	.0	.0	.0	

FIGURE 33. WIND DIRECTION AND SPEED, SEPTEMBER.

WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	2.2	4.2	4.9	1.8	.3	.0	.0				
NNE	1.6	4.0	4.4	1.1	.1	.1	.0				
NE	1.7	3.9	4.2	.7	.1						
ENE	.7	1.9	2.6	.8	.1	.0					
E	.8	1.7	2.4	.8	.1						
ESE	.3	.8	1.8	1.1	.1	.0					
SE	.4	1.0	2.0	.7	.0	.0					
SSE	.6	1.4	2.5	1.1	.1	.0					
S	.8	2.0	2.6	.6	.1	.0	.0				
SSW	.3	1.2	1.7	.5	.0	.0					
SW	.3	.8	1.0	.3	.0						
WSW	.2	.4	.5	.2	.0						
W	.3	.6	.6	.2	.0						
WNW	.3	.5	.9	.2	.0						
NW	.5	1.3	1.2	.4	.0						
NNW	.8	1.4	1.8	.8	.2	.0					
CALM									TOTAL CALM % = 13.6		
	11.9	26.9	34.9	11.2	1.2	.2	.1				

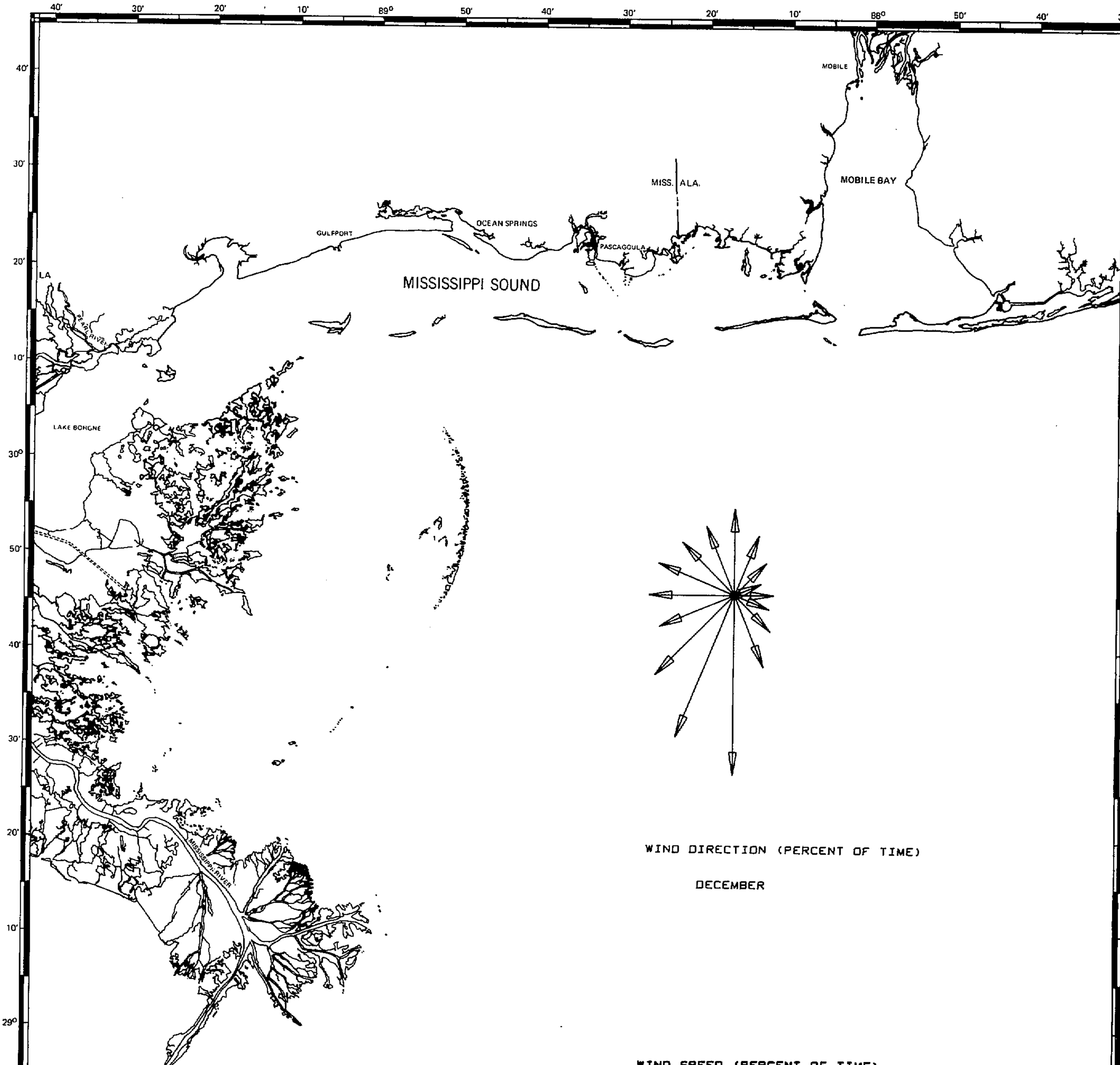
FIGURE 34. WIND DIRECTION AND SPEED, OCTOBER.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥56
N	2.2	3.2	4.9	2.7	.5	.0					
NNE	1.8	2.8	3.9	1.9	.3	.0					
NE	1.4	2.7	3.0	.6	.1	.1	.0				
ENE	.8	1.8	2.3	.4	.0						
E	.9	1.8	2.0	.5	.0						
ESE	.4	1.1	2.4	1.1	.0						
SE	.3	.9	2.5	1.3	.0						
SSE	.5	1.2	2.6	1.1	.1	.0					
S	.6	1.8	2.3	.7	.1						
SSW	.4	1.2	1.9	.6	.1	.0					
SW	.3	.7	1.3	.6	.0						
WSW	.2	.4	.7	.4	.0	.0					
W	.5	.8	.7	.2	.0						
WNW	.4	.6	1.0	.4	.1	.0					
NW	.8	1.0	1.4	.7	.1	.0	.0				
NNW	1.0	1.1	2.0	1.4	.4	.1					
CALM									TOTAL CALM % = 12.0		
	12.5	23.3	35.1	14.8	2.0	.3	.0				

FIGURE 35. WIND DIRECTION AND SPEED, NOVEMBER.



WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	1.9	2.7	4.3	2.6	.7	.1	.0				
NNE	1.4	2.6	3.9	1.9	.6	.0					
NE	1.4	2.3	3.0	.8	.1	.0					
ENE	.9	1.5	2.5	.6	.0						
E	.7	1.9	2.5	.7	.1						
ESE	.4	1.2	2.6	1.2	.1						
SE	.5	1.1	2.5	.9	.1						
SSE	.5	1.4	2.3	.8	.1						
S	.9	1.6	2.7	.7	.1	.0					
SSW	.5	1.1	2.0	.7	.1						
SW	.4	.9	1.5	.3	.0	.0					
WSW	.2	.6	.8	.3	.1						
W	.6	.7	1.0	.4	.1						
WNW	.4	.7	1.0	.4	.2	.0					
NW	.5	.8	1.3	.7	.2	.0					
NNW	.6	1.2	1.9	1.3	.3	.0	.0				
CALM									TOTAL CALM % = 12.8		
	11.9	22.3	35.7	14.4	2.6	.3	.0				

FIGURE 36. WIND DIRECTION AND SPEED, DECEMBER.

WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	≥ 56
N	.9	2.1	4.2	2.6	.5	.1	.0				
NNE	.9	2.3	4.4	2.4	.5	.2	.0				
NE	1.0	2.1	3.0	1.2	.2	.1	.0				
ENE	.7	1.6	2.7	.9	.1	.0	.0	.0			
E	.5	1.5	2.9	1.2	.2	.0	.0				
ESE	.3	.9	3.5	2.6	.4	.1	.0				
SE	.4	1.0	3.3	2.2	.4	.0					
SSE	.4	1.3	3.9	2.6	.5	.1	.0				
S	.5	1.4	3.3	1.8	.3	.1	.0				
SSW	.3	.8	2.0	1.4	.2	.0	.0		.0		
SW	.2	.6	1.3	.6	.1	.0					
WSW	.1	.5	.9	.4	.1	.0					
W	.3	.7	1.0	.3	.1	.0					
WNW	.2	.5	.8	.4	.2	.0	.0				
NW	.3	.5	.9	.7	.2	.0					
NNW	.4	.7	1.5	1.2	.4	.1	.0	.0			
CALM									TOTAL CALM % = 6.6		
	7.2	18.6	39.7	22.5	4.4	.9	.2	.0	.0		

FIGURE 37. WIND DIRECTION AND SPEED, YEAR.

Surface Circulation as Inferred from Surface Drifters

Surface drifters were employed during 1964 and 1965 over the northeast Gulf shelf area to provide supplemental data on the surface circulation. Results of the surface drifter study, when considered in conjunction with the previously discussed spatial distribution of density, add substantially to the understanding of the shelf hydrography.

The surface drifters utilized were 4/5 pint, clear-glass bottles containing a numbered and prepaid postal card addressed to the investigating institution. A ballast of dry sand was added to the bottles to assure a vertical orientation of the bottles afloat and to minimize the amount of exposed-surface area thus reducing the direct influence of the wind.

Reported recoveries from each surface-drifter release location were divided into quadrants according to the direction determined from the release to recovery point. Figures 38-45 illustrate the prevailing surface drift determined from the use of surface drifters. The length of the vectors corresponds to the speed in nautical miles per day. The speed is based on the first recovery for a particular quadrant of the release point. The number of surface drifters deployed and the percentage recovered are shown in parenthesis by each release point. The dot-dash pattern used in constructing the drift vectors has an associated key appearing in the legends of the illustrations which furnishes the percent recovered from each quadrant. Surface drifters recovered from the east coast of Florida, to avoid confusion, were assigned a southeast orientation of the drift vector. As the path of the drifters often assumes a course other than straight, the conclusions concerning surface drift must be determined in view of the previously discussed density fields and prevailing winds.

The surface circulation for January 1965, as determined from surface drifters is depicted in Figure 38. A counterclockwise circulation around a well-developed eddy over the shelf results in a surface transport to the southeast and west. While surface drifters were recovered west of the Mississippi River along the Louisiana coast, their speeds were much less than those transported to the southeast.

If the April 1965 drift results (Figure 39) are studied jointly with the spatial distribution of surface density for the same period (Figure 16), it can be seen that there is good agreement between the two. The presence of the cyclonic eddy over the shelf is again substantiated by the pattern of drift vectors.

The surface-drift data of April 1964 (Figure 40) suggest a flow from the south moving in a cyclonic manner over the shelf. From the vicinity of the 500-fathom isobath of the upper DeSoto Canyon, there is a westward flow along the shelf at speeds approaching two knots.

The surface drift during May 1965 (Figure 41) was primarily to the north as indicated by the large number of recoveries from the coasts and barrier islands of Mississippi and Alabama. The density distribution (Figure 18) for the same period shows that the cyclonic eddy was weakly developed during this time, but that the Loop Current had probably extended further north altering the shelf circulation. It should be remembered that the winds during May (Figure 29) are primarily from the south.

The surface current south of the Mississippi River Delta was oriented to the northeast during May 1964 (Figure 42). There appears to be a bifurcation of this current south of Pensacola, Florida, at the apex end of DeSoto Canyon. The resulting branches flow to the southeast and to a more northerly course. The lighter water flowing out of Mobile Bay (Figure 19) appears to have sufficient momentum to prevent the occurrence of the usual near-shore surface flow to the southwest.

In late June and early July 1964 (Figure 43) the surface drift was generally toward the southeast. The distribution of surface drifter recoveries reported from along the northwest coast of Florida suggests the presence of a current paralleling the edge of the shelf. The presence of this current (Figure 20) is probably due to the drag of the subsurface, heavier waters on the unusually large amount of lighter waters over the shelf.

The surface currents of July 1965 (Figure 44) show a current flowing to the northeast along the shelf from south of the Mississippi Delta and dividing over the DeSoto Canyon south of Pensacola, Florida. One branch flows to the west generating a cyclonic circulation west of the Canyon south of Mississippi-Alabama. The other branch flows to the east producing an anti-cyclonic eddy east of the Canyon around the less dense waters.

The surface circulation implied by surface drift for September 1964 (Figure 45) is in good agreement with the distribution of surface densities for the same period (Figure 22). There existed a northeast flow south of the Delta and a cyclonic circulation over the shelf region. A portion of the surface drifters deployed south of the Mississippi Delta was recovered west of the Delta suggesting a westward transport immediately south of South Pass. The winds during September (Figure 33) are primarily from the northeast and likely influenced the resulting drift trajectories.

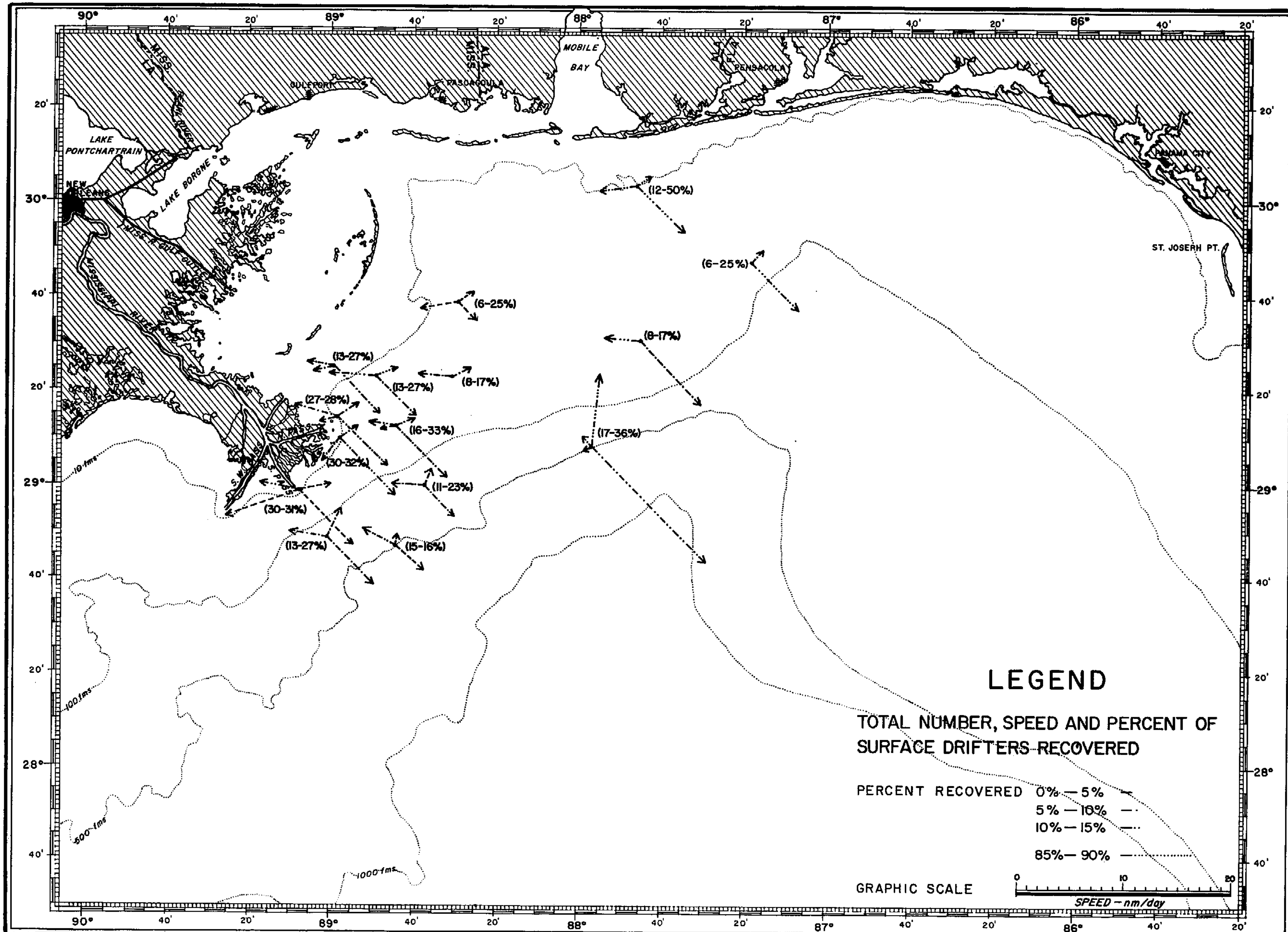


FIGURE 38. SURFACE DRIFT 11 - 14 JANUARY, 1965.

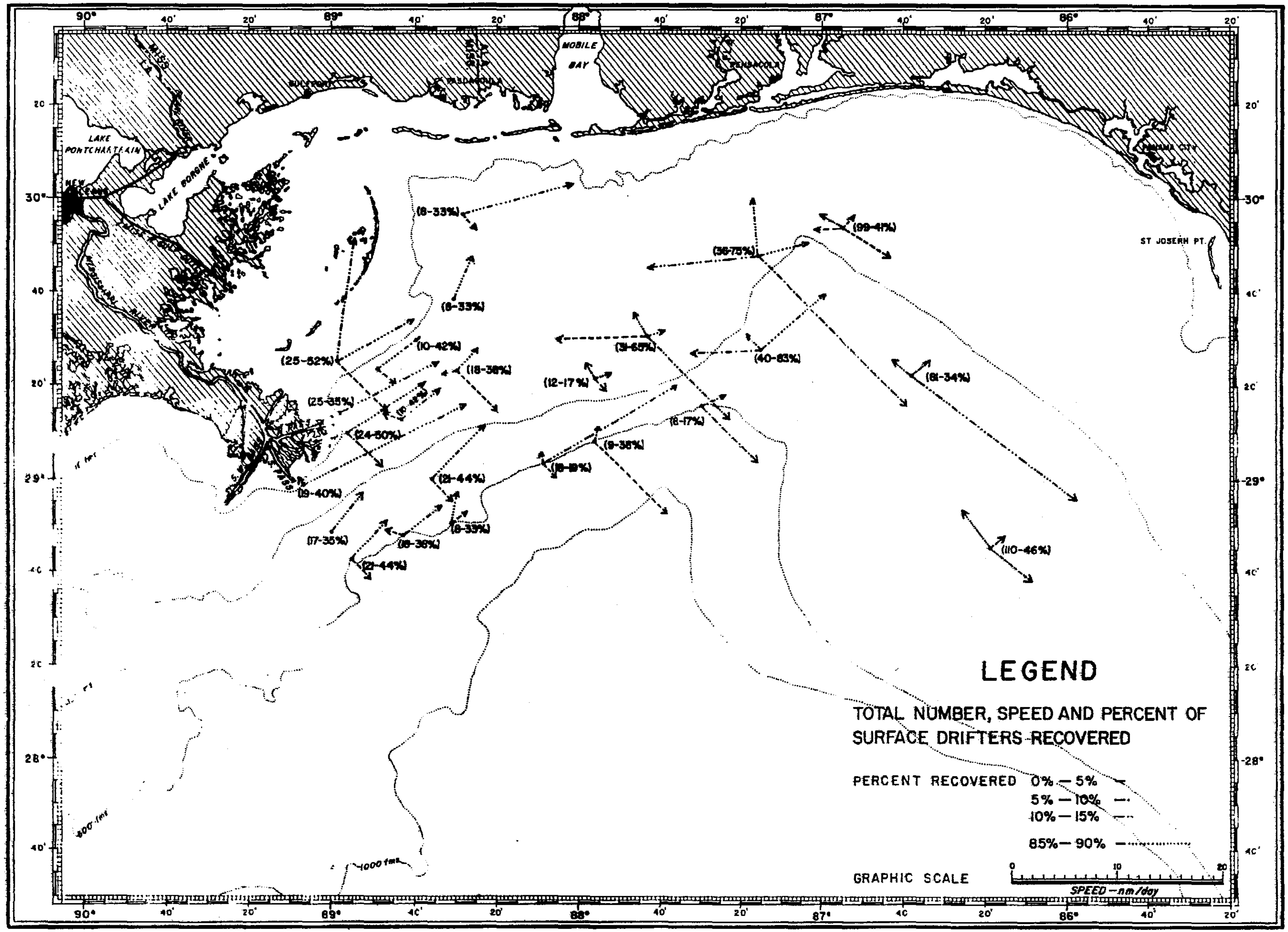


FIGURE 39. SURFACE DRIFT 31 MARCH - 9 APRIL, 1965.

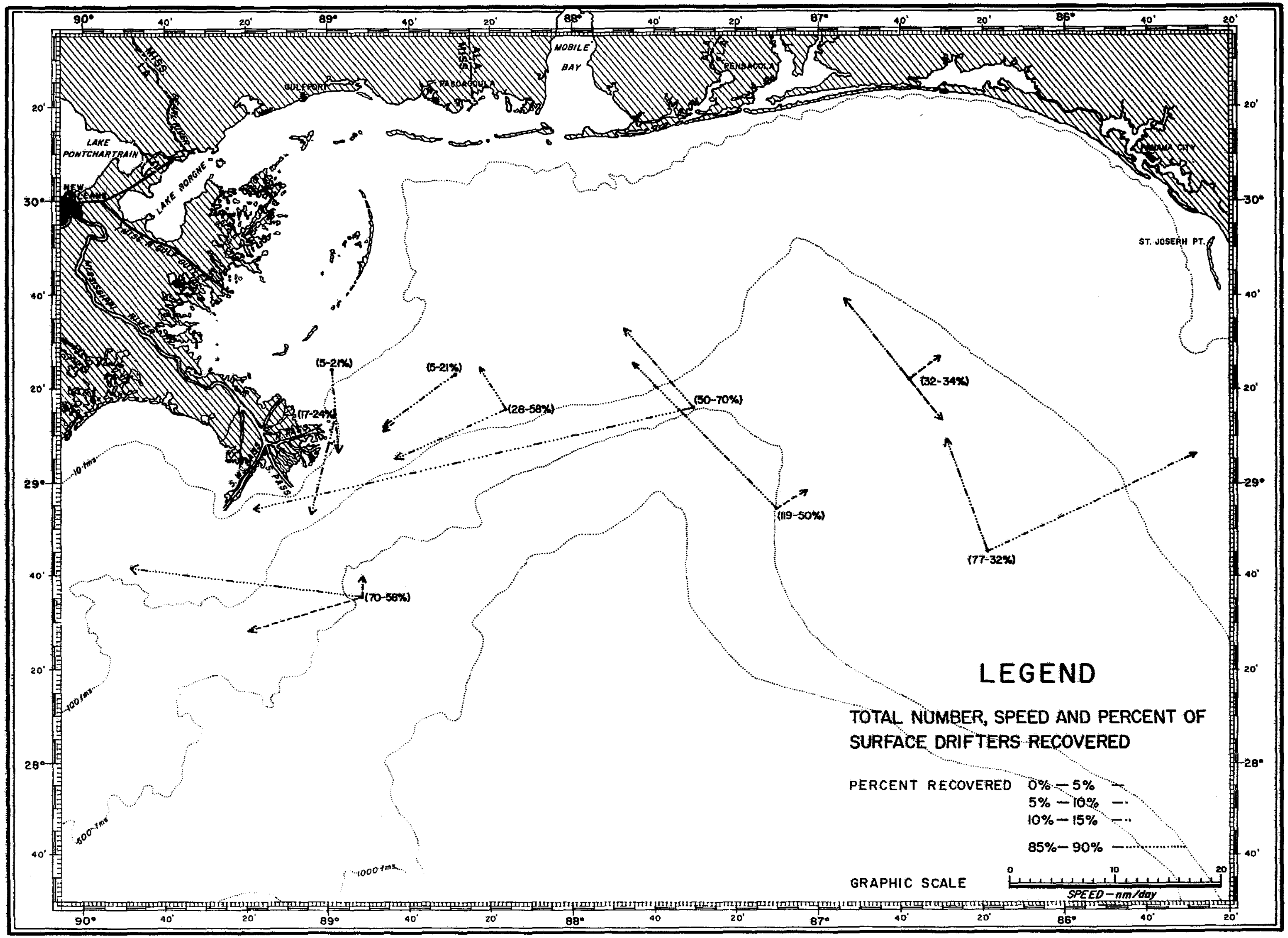


FIGURE 40. SURFACE DRIFT 10 - 12 APRIL, 1964.

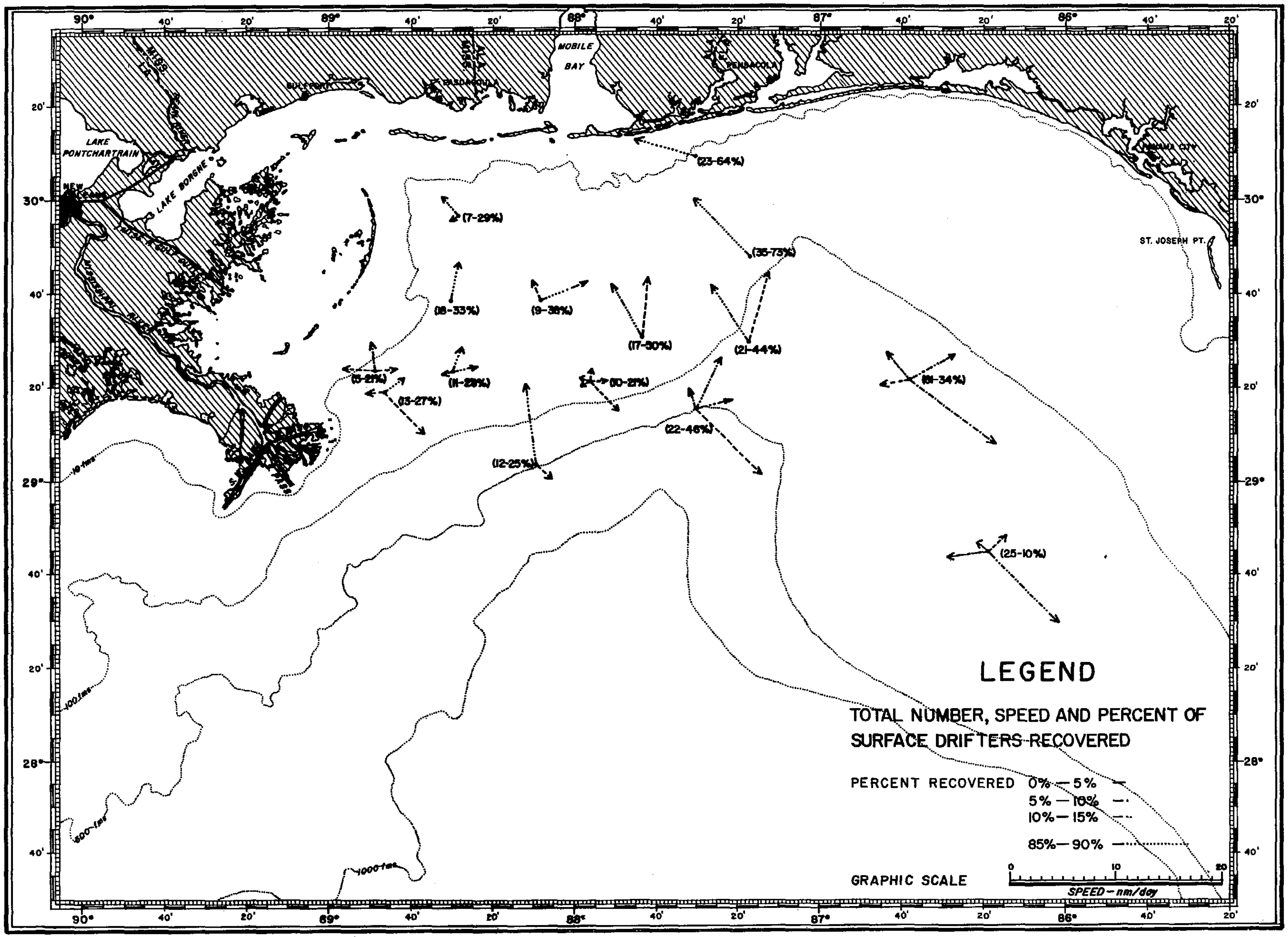


FIGURE 41. SURFACE DRIFT 10 - 14 MAY, 1965.

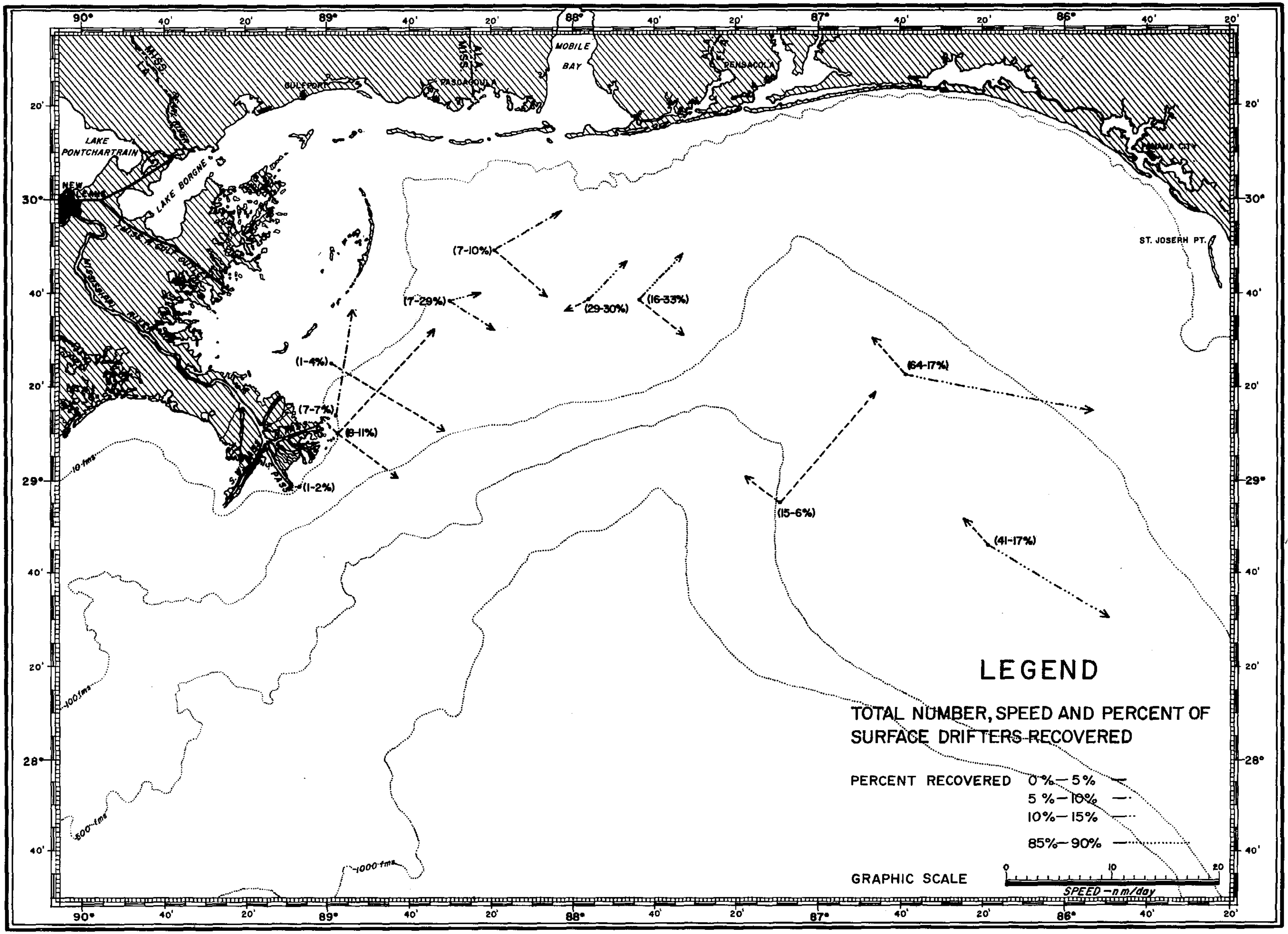


FIGURE 42. SURFACE DRIFT 24 - 31 MAY, 1964.

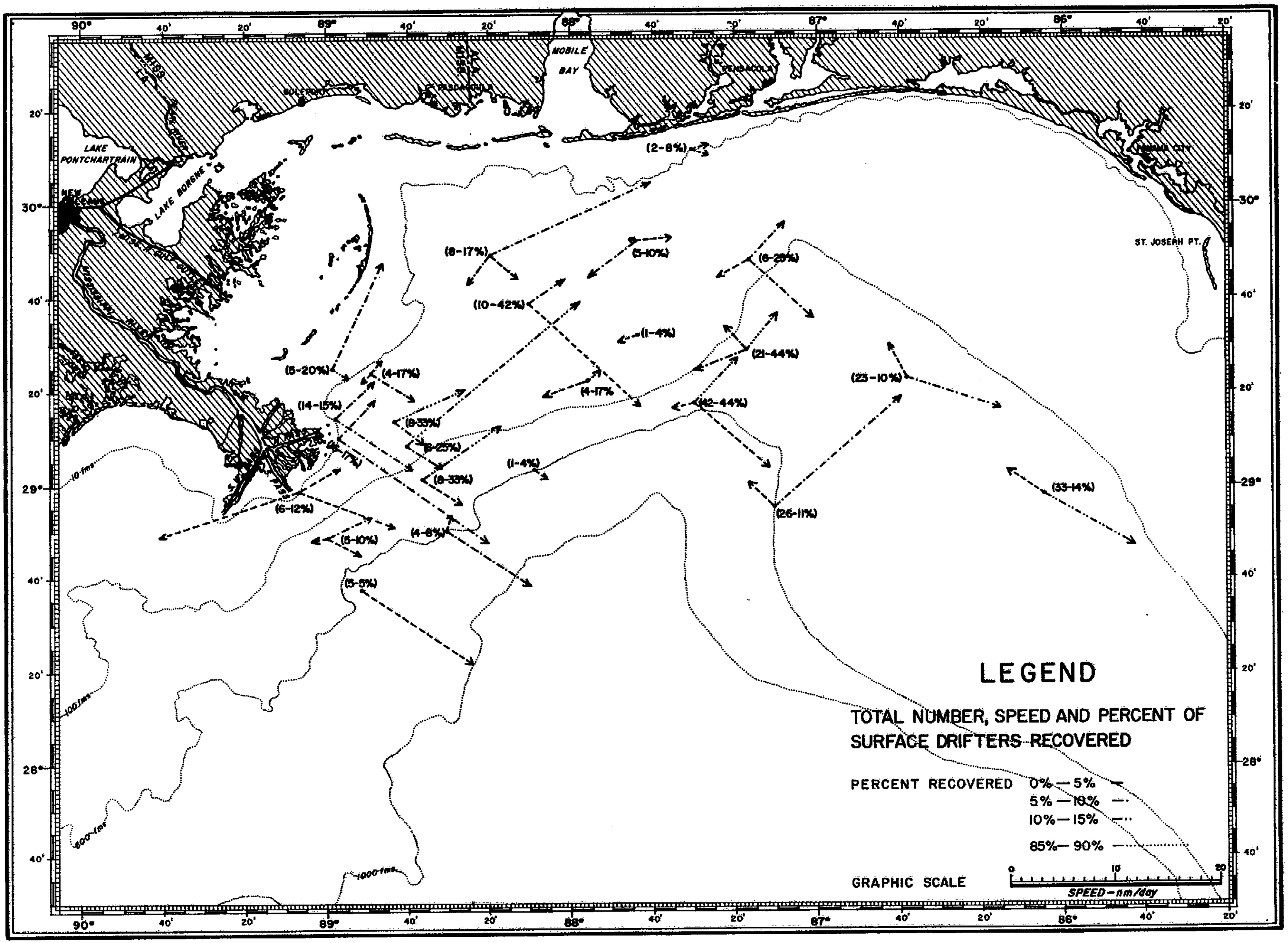


FIGURE 43. SURFACE DRIFT 19 JUNE - 3 JULY, 1964.

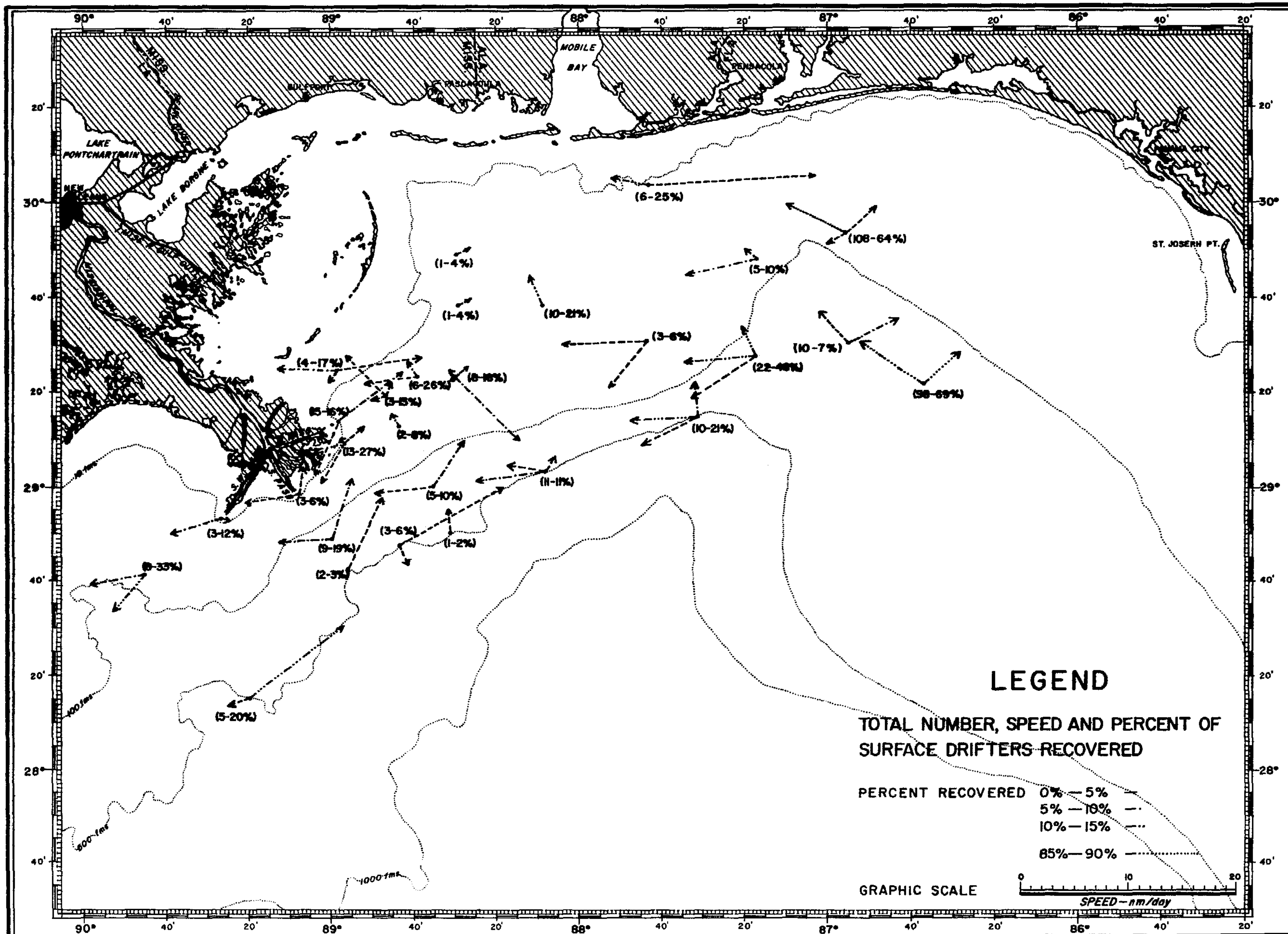


FIGURE 44. SURFACE DRIFT 19 - 24 JULY, 1965.

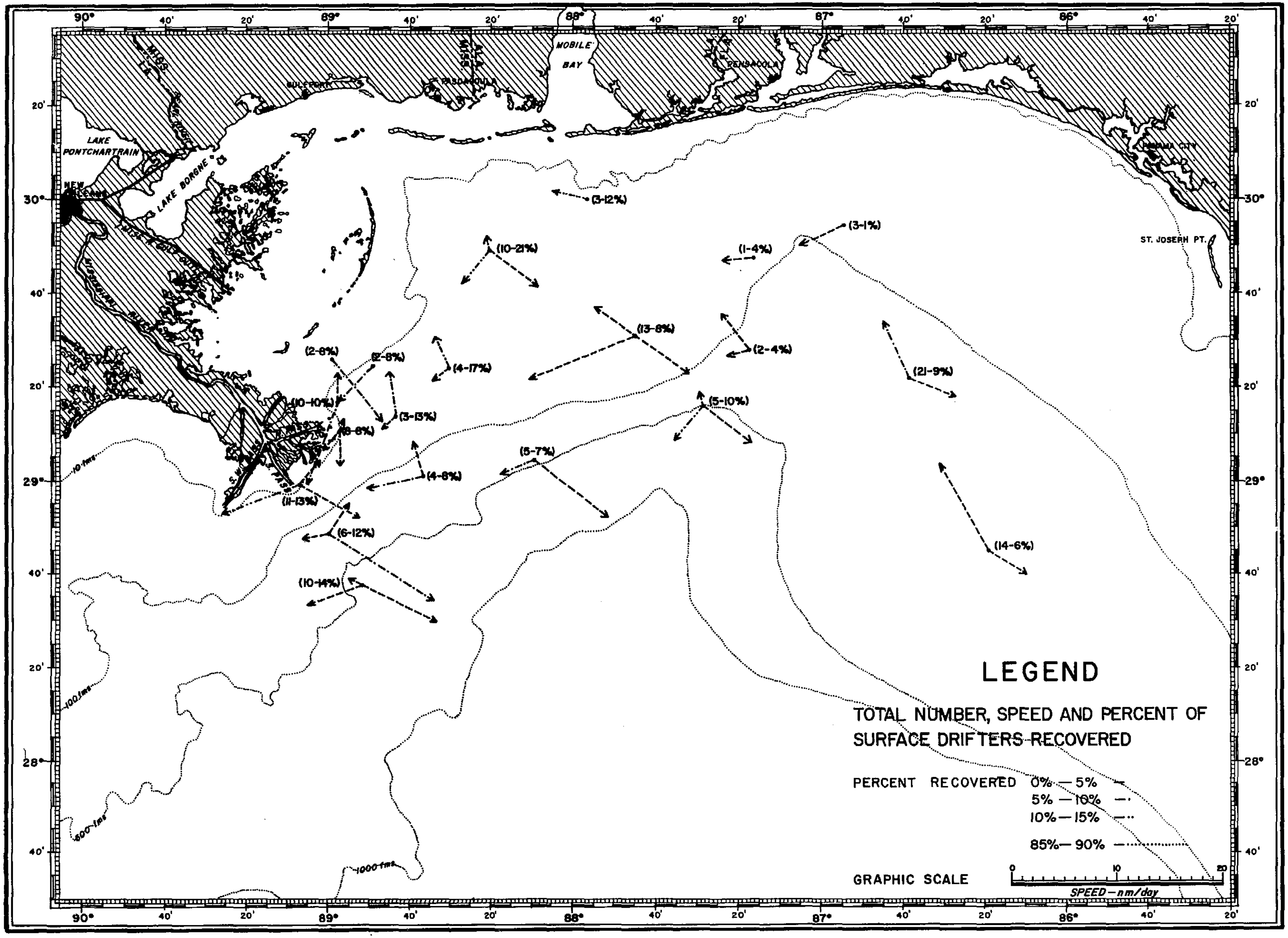


FIGURE 45. SURFACE DRIFT 31 AUGUST - 5 SEPTEMBER, 1964.

Wind Rose Projections

In addition to the geostropic surface flow transporting oil in the event of a spill, wind would also have a significant effect upon the path the spill would take. The assumptions were made that the spill would be transported at the rate of .037 of the wind speed and deflected 45 degrees to the right. The average monthly wind speed for each direction was used in computation of the projected paths. The probability that the spill would be carried in any one of the 16 directions considered is found just exterior to the projections (Figures 46-57). The probability, the larger numbers corresponding to the greater probability, was determined by the percentage of time the wind was oriented in a given direction. The shaded inner portion is the projected distance that a spill would travel in 24 hours with the outer boundary representing the 48-hour projection. The configuration boundary does not represent the shape or areal extent of an oil spill.

The period of greatest threat of a spill traveling toward the mainland is during the summer and fall. However, due to the reduced strength of summer winds, a spill would probably progress at a slower speed during this period.

It should be realized that these projections are based on winds alone and therefore do not include the effect of the prevailing shelf circulation or river discharges on the trajectory.

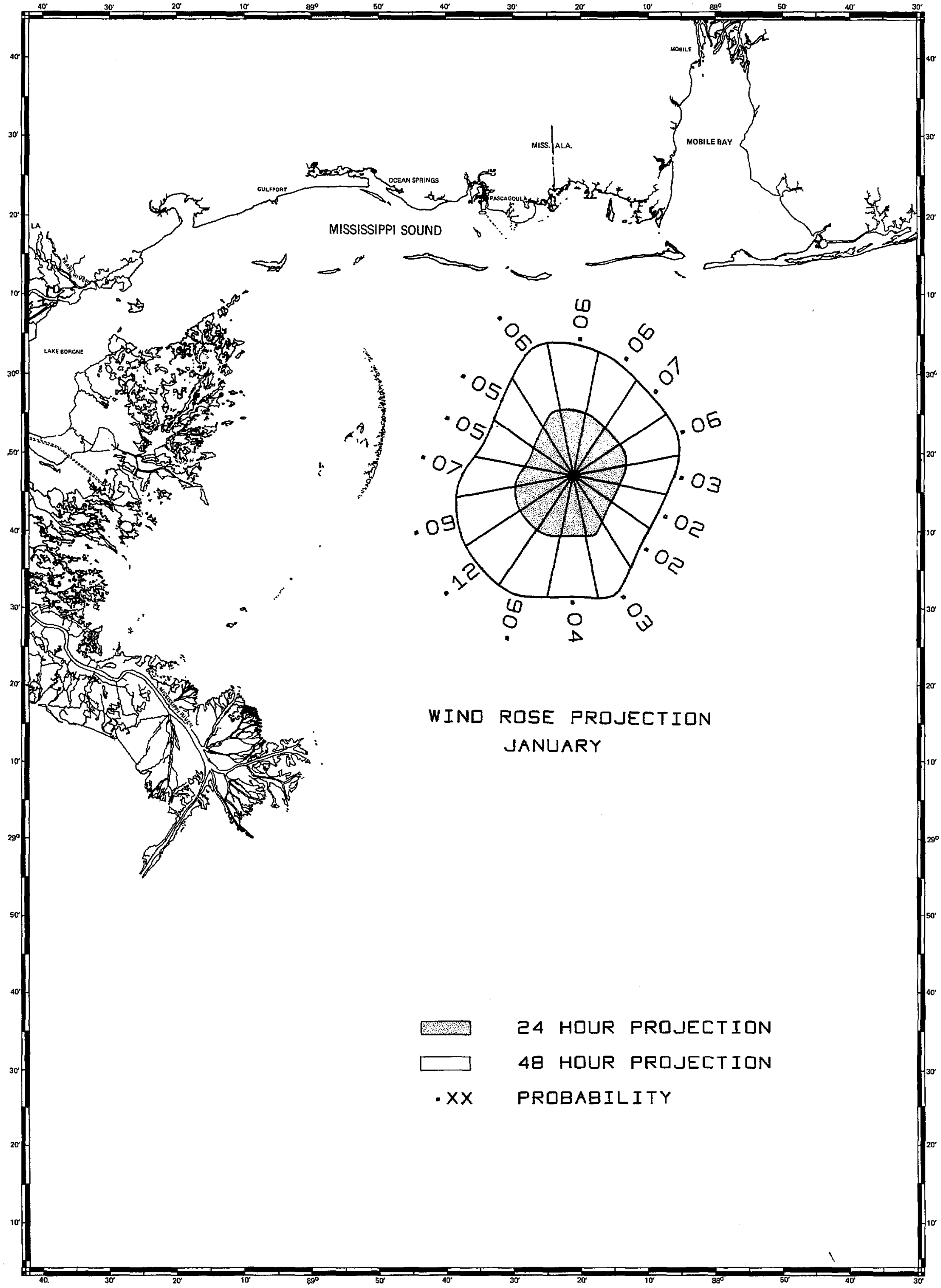


FIGURE 46. WIND ROSE PROJECTION, JANUARY.

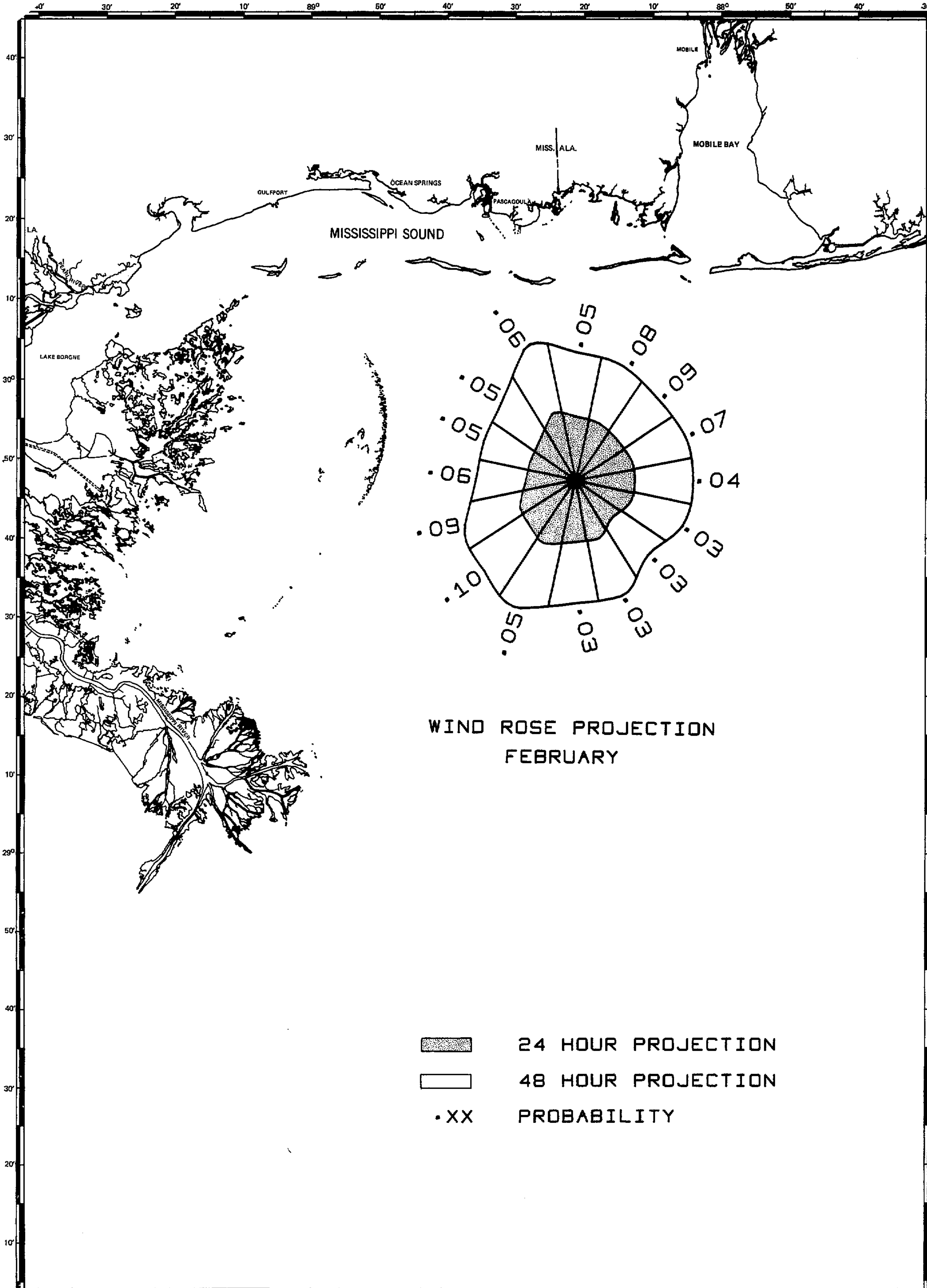


FIGURE 47. WIND ROSE PROJECTION, FEBRUARY.

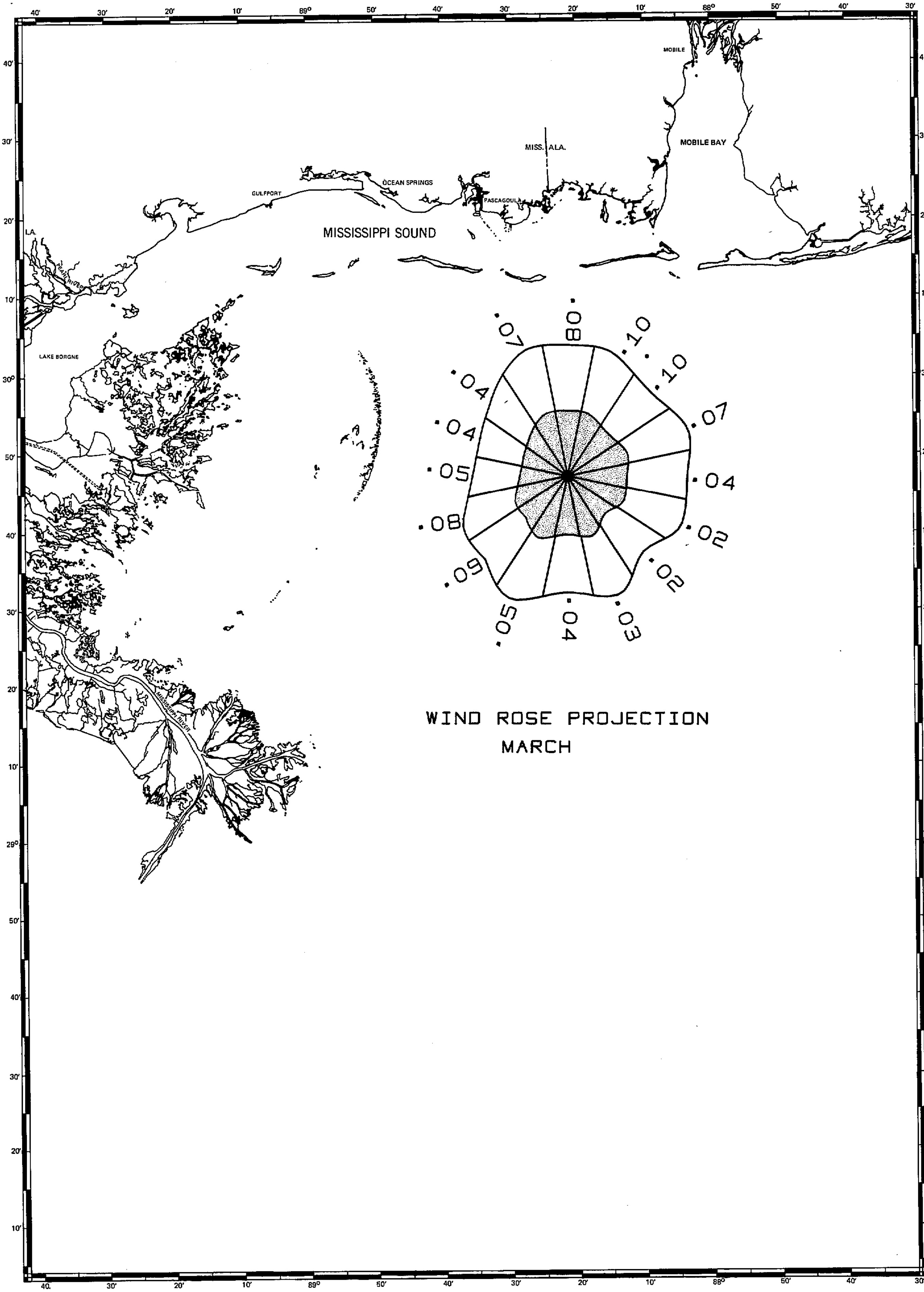


FIGURE 48. WIND ROSE PROJECTION, MARCH.

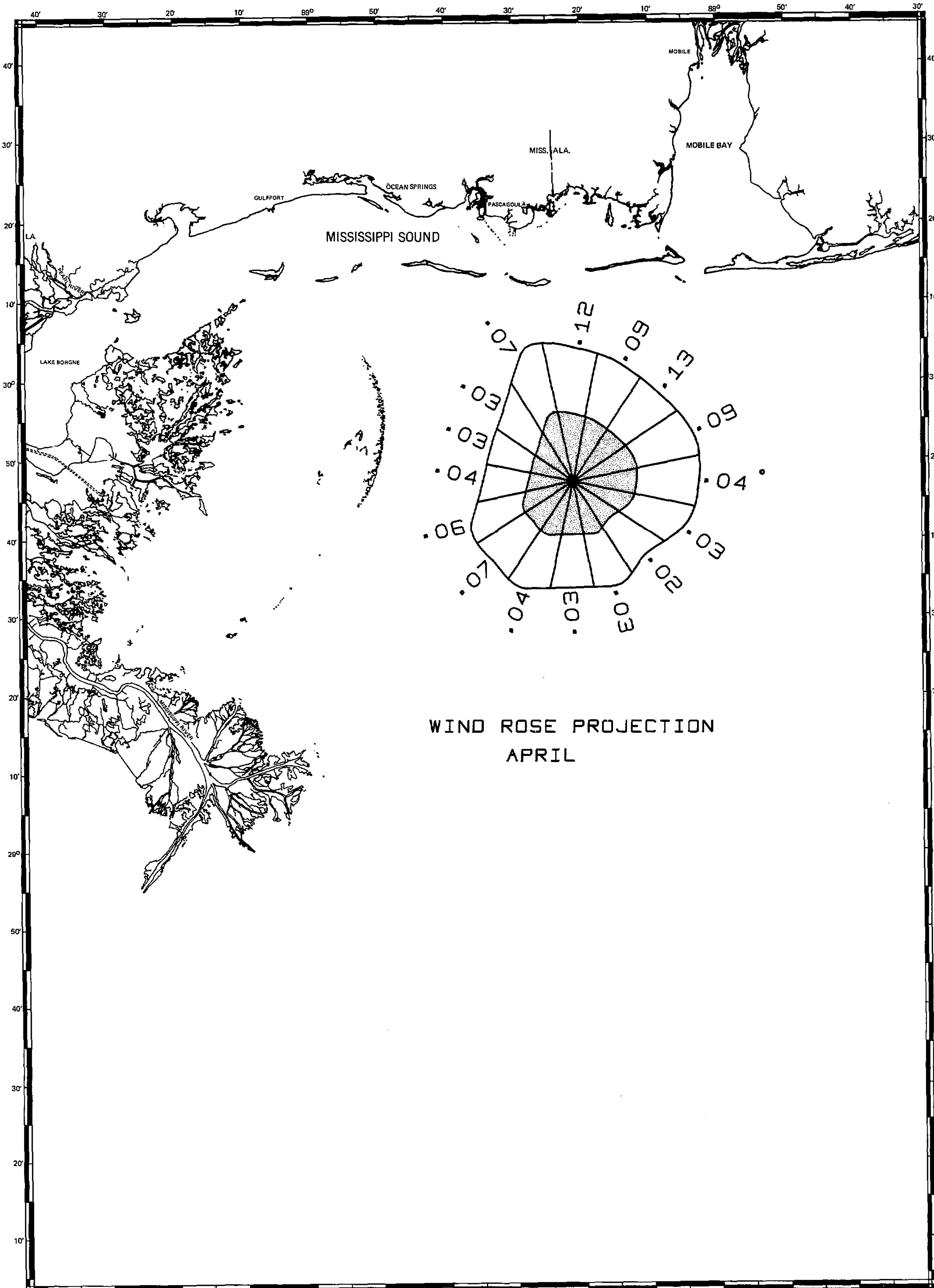


FIGURE 49. WIND ROSE PROJECTION, APRIL.

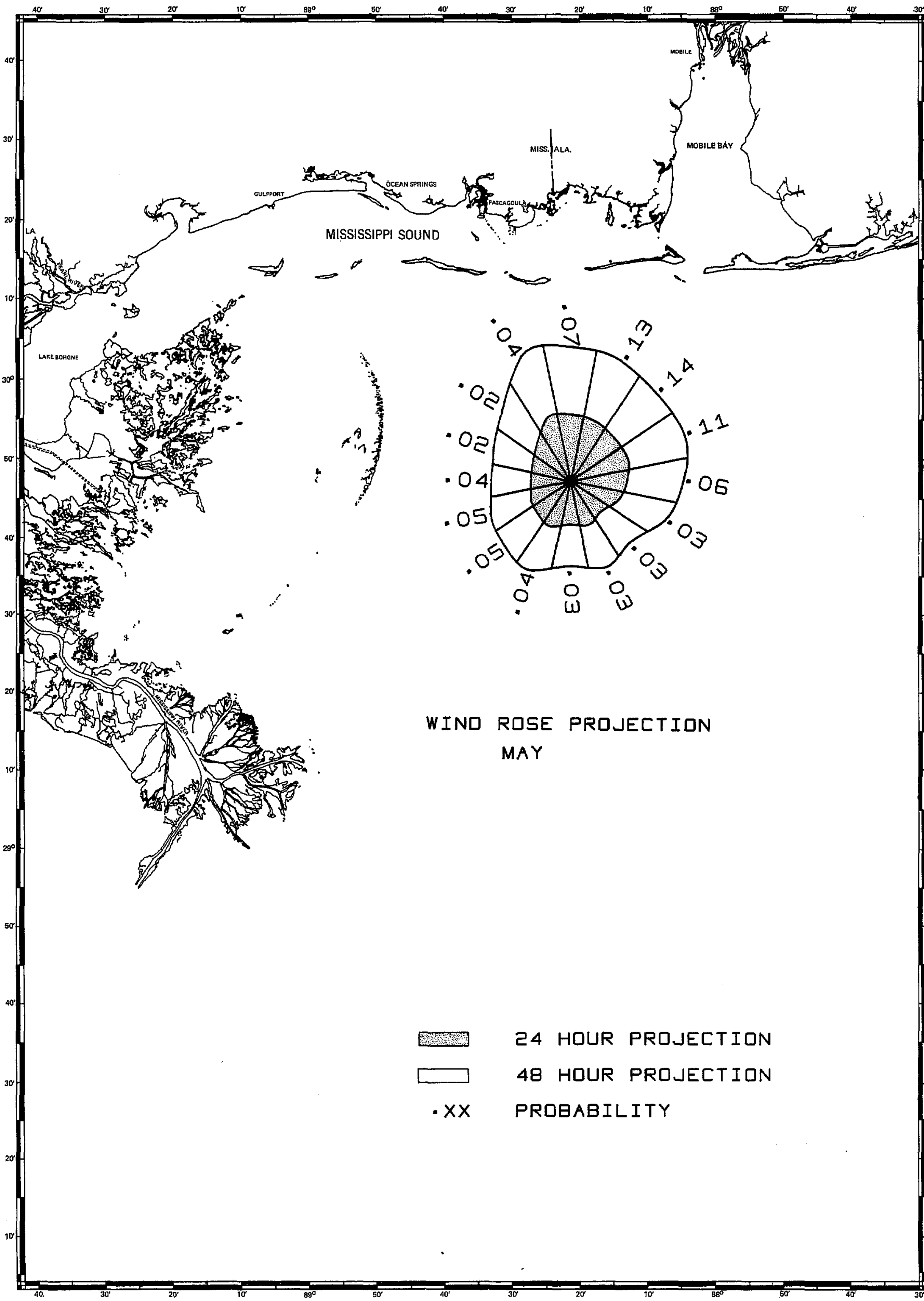


FIGURE 50. WIND ROSE PROJECTION, MAY.

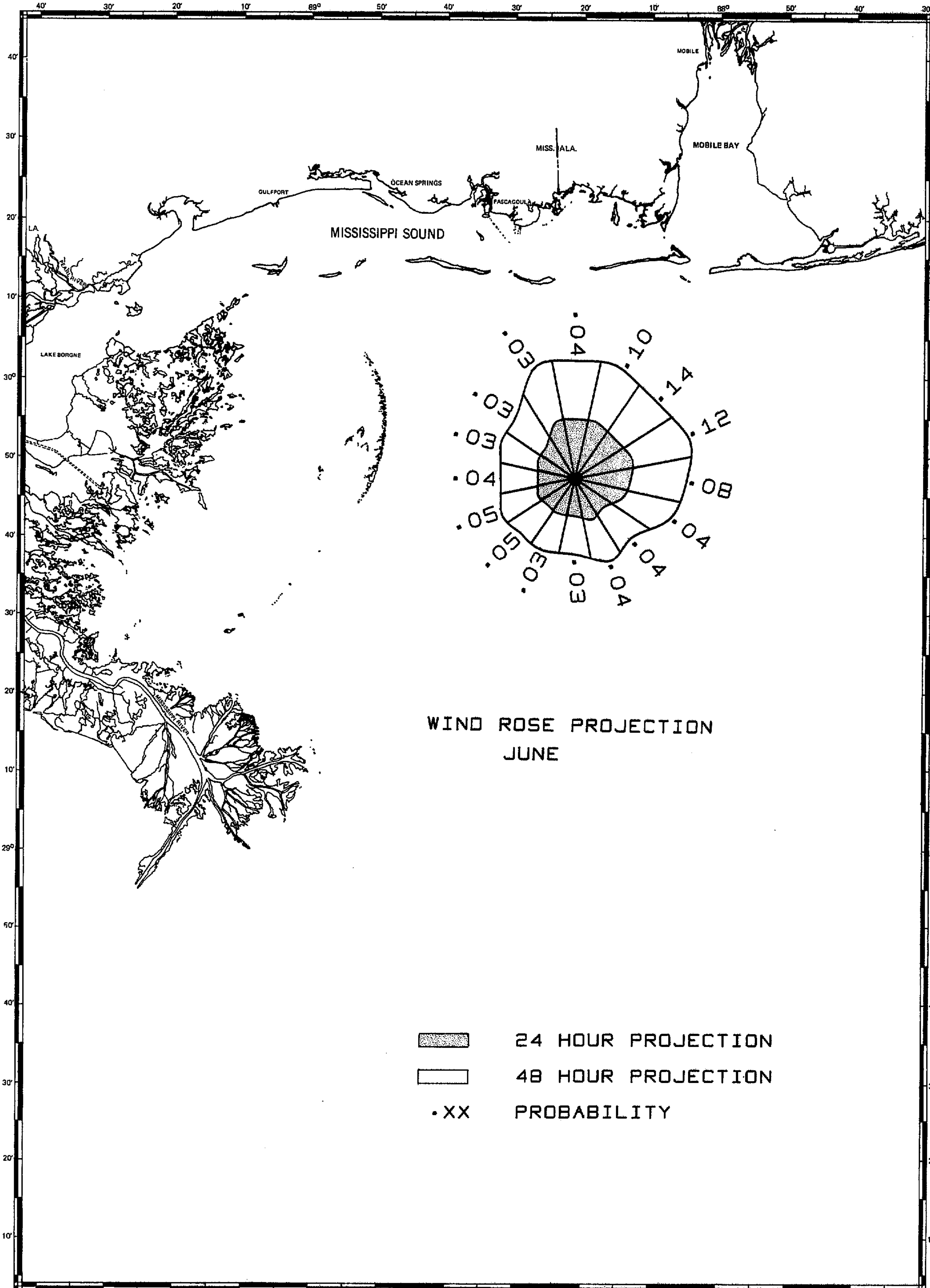


FIGURE 51. WIND ROSE PROJECTION, JUNE.

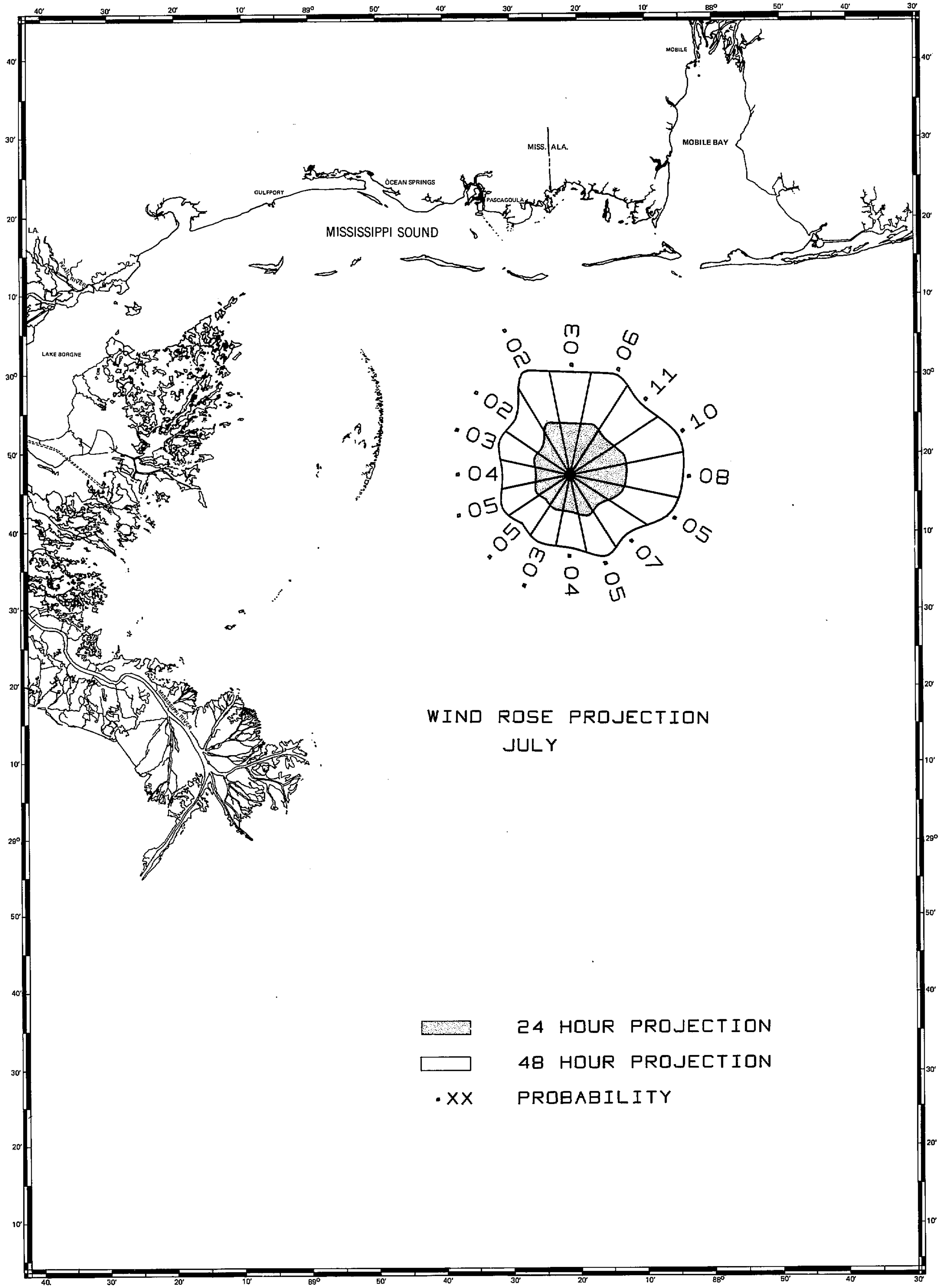


FIGURE 52. WIND ROSE PROJECTION, JULY.

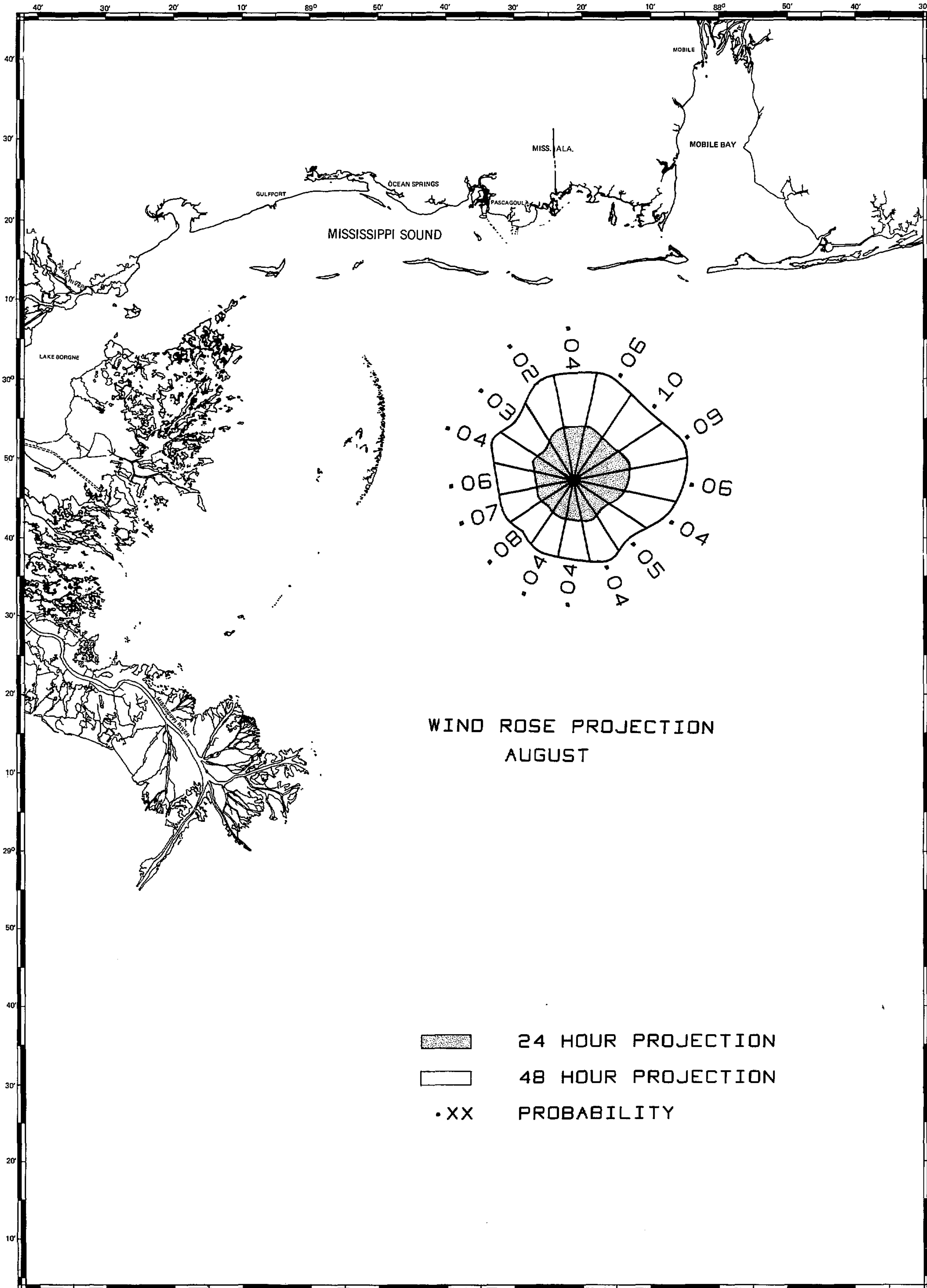


FIGURE 53. WIND ROSE PROJECTION, AUGUST.

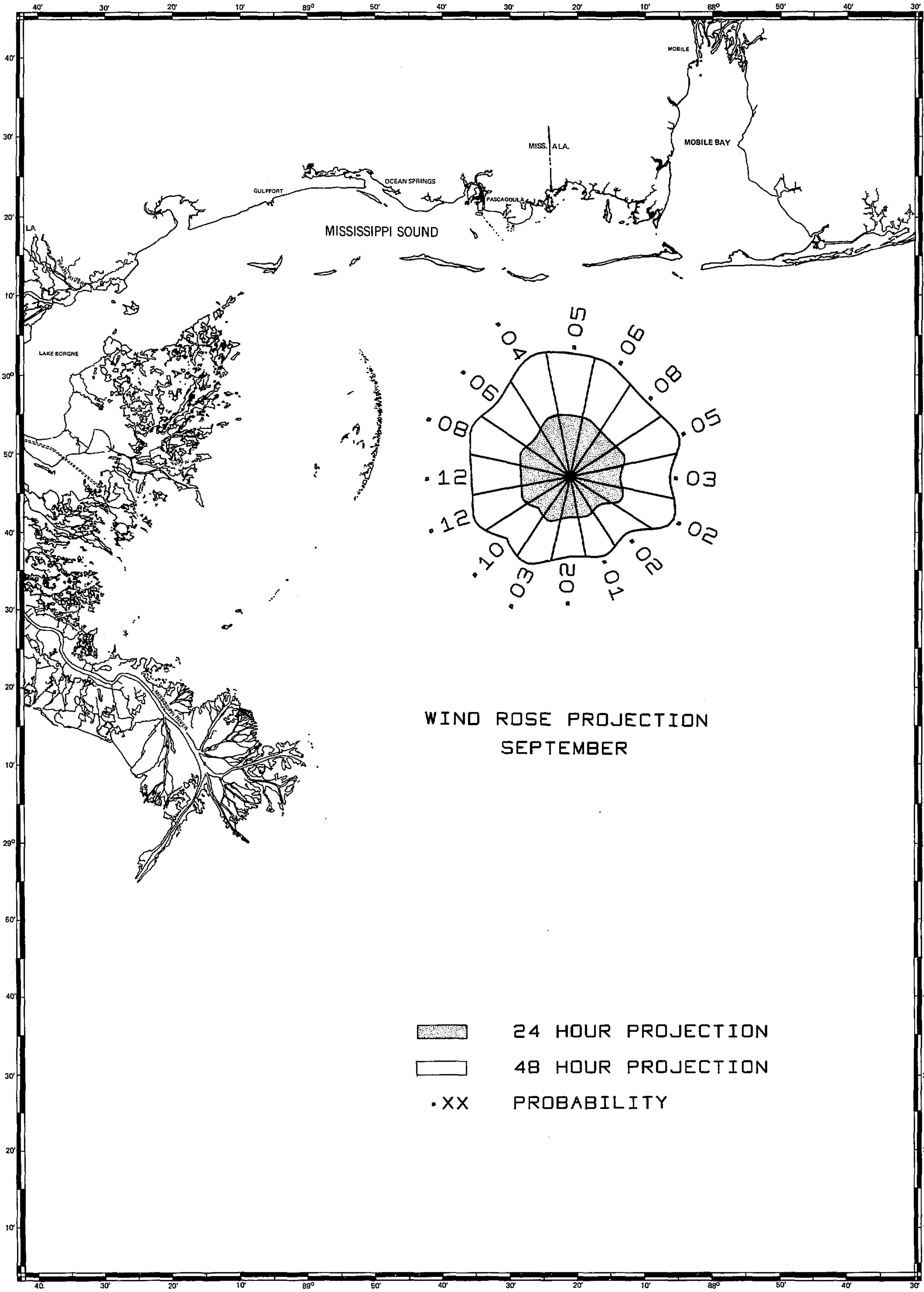


FIGURE 54. WIND ROSE PROJECTION, SEPTEMBER.

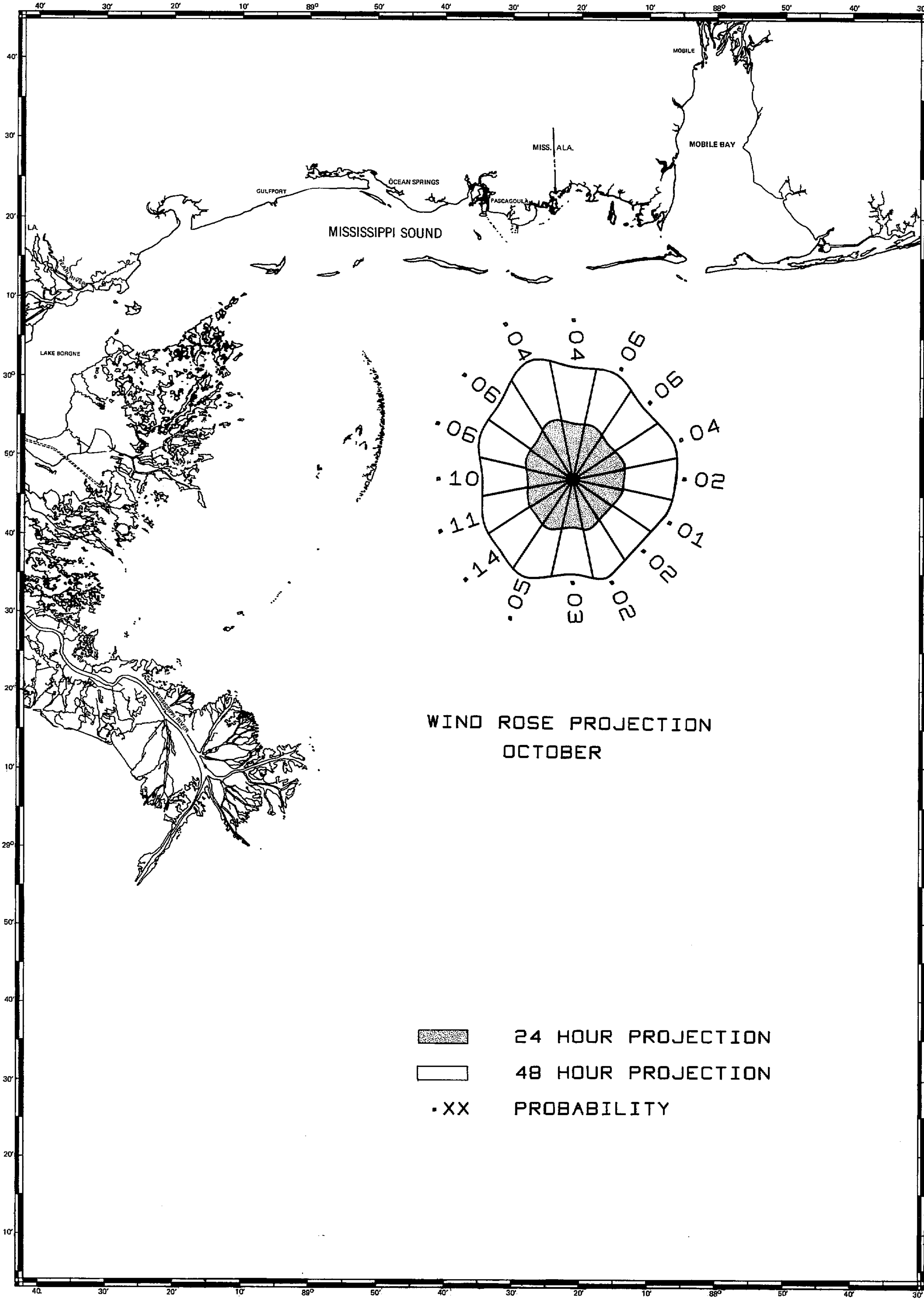


FIGURE 55. WIND ROSE PROJECTION, OCTOBER

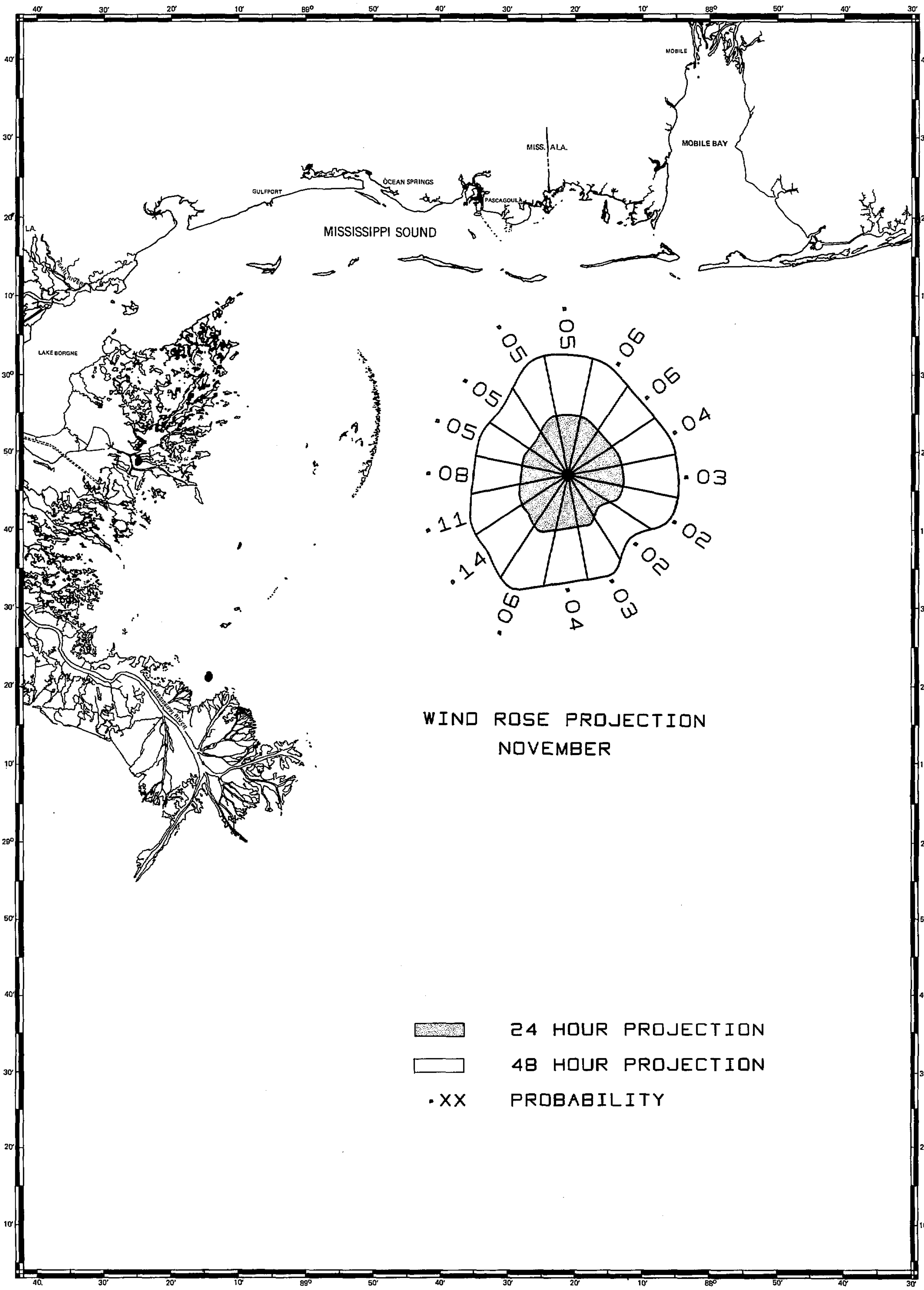


FIGURE 56. WIND ROSE PROJECTION, NOVEMBER.

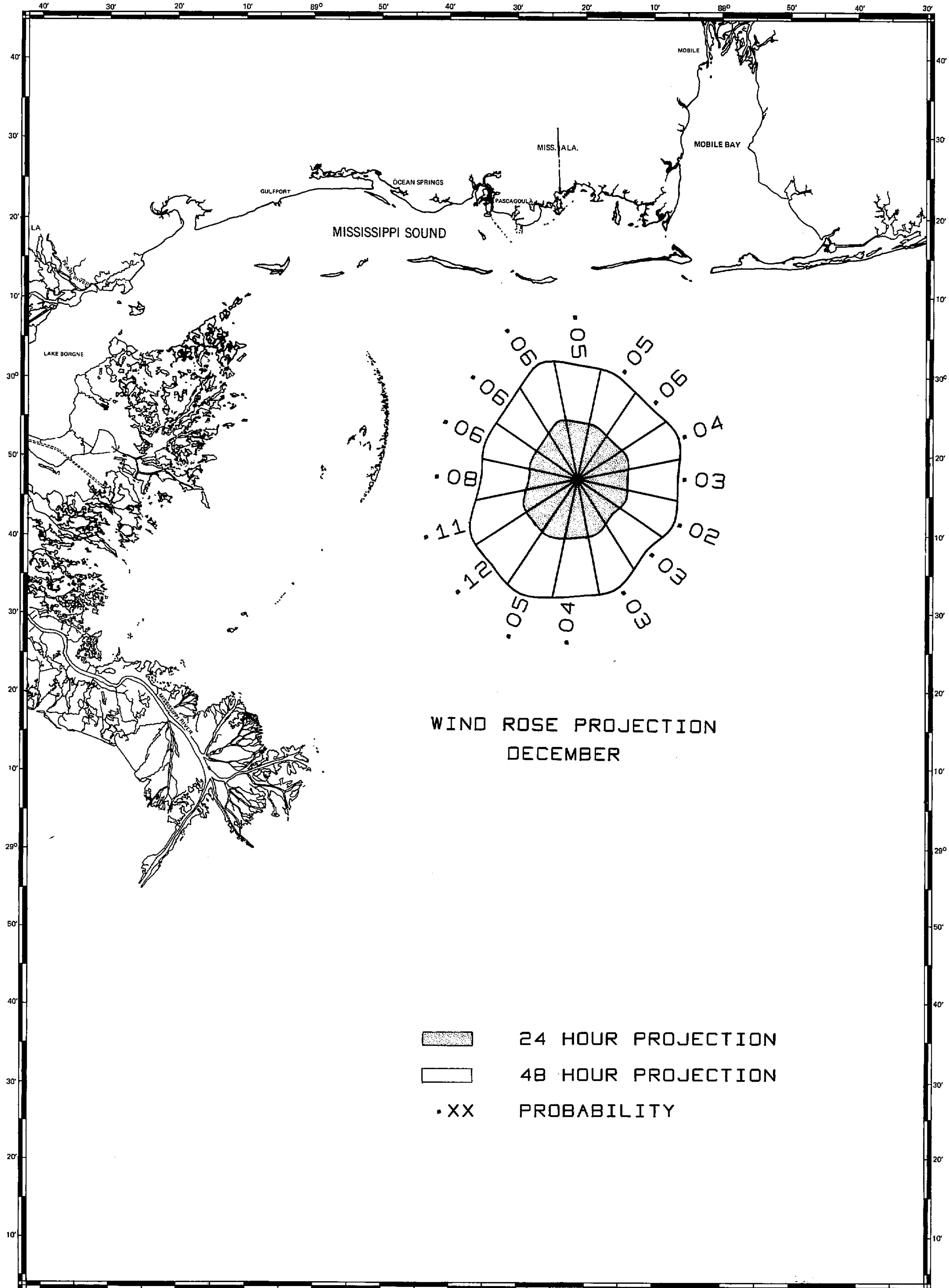


FIGURE 57. WIND ROSE PROJECTION, DECEMBER.

PHOTO 3. NESTING PELICANS ON CHANDELEUR ISLANDS.

Donald Edwards

Wave Height Statistics

Water wave heights and frequency of occurrence are important considerations in the construction, installation, and operation of an offshore Superport monobuoy. Offshore construction or operation can be hampered or halted during periods when waves attain heights that make continued activity hazardous to men, equipment, and the marine environment. Judicious planning to assure meeting construction and operation schedules must include careful consideration of the wave climate. Knowledge of the existing sea state (wave heights) that can be expected during a given time is also essential to the development of a contingency plan for oil containment and cleanup in the event of a spill.

The wave statistics discussed herein were determined for the rectangular area described by the following coordinates: 28°45'N, 87°30'W; 30°00'N, 87°30'W; 30°00'N, 89°30'W, 28°45'N, 89°30'W. This area encompasses the proposed site for the monobuoy located south of Pascagoula, Mississippi. The wave statistics were computed from an extensive analysis of meteorological information.

Figures 58-69 are wave height histograms consisting of the seven most commonly used height divisions and depicting the frequency as a percentage of time. During the hurricane season, 1 June through 30 November, seas well in excess of 12 feet occur but because the frequency of hurricane occurrence is too small to substantially influence these data, waves associated with hurricanes are not included.

The month of January (Figure 58) shows the largest percentage of time, 13 percent, when waves are greater than 12 feet. However, 77 percent of the time the wave heights are less than 7 feet and 30 percent of the time the wave climate ranges from calm to 3 feet.

While February (Figure 59) has a smaller frequency of waves in excess of 12 feet, there is a greater frequency, 30 percent, of waves higher than 7 feet. Even during this month of greatest "roughness," a sea state where waves range from 0 feet (calm) to 3 feet accounts for 23 percent of the time.

The wave climate during March (Figure 60) is considerably milder with waves smaller than 7 feet occurring 81 percent of the time. Thirty-one percent of the time waves of 3 feet or less prevailed.

April (Figure 61) displays a frequency-shift to larger waves in the lower 0-5 foot range with the frequencies of the wave-height intervals above 5 feet remaining almost unchanged from the previous month. Waves greater than 7 feet account for 19 percent of the time while the frequency of waves greater than 12 feet amounts to only 3 percent.

Figure 62 indicates a significant reduction in the height of waves occurring in May. The range of sea state from calm to waves of 5 feet prevails 80 percent of the time.

June (Figure 63) shows a continuation of the trend to a calmer sea. Ninety-three percent of the time the waves are less than 7 feet. Seas in excess of 12 feet amounted to a frequency of less than 1 percent.

While the wave climate in July (Figure 64) is predominantly less than 5 feet, there is an increase in the frequency of occurrence of waves greater than 7 feet.

The sea is calmest during August (Figure 65) with waves of less than 5 feet occurring 86 percent of the time. Waves of 1 foot or less account for 25 percent of the time with waves greater than 12 feet amounting to a frequency of less than 1 percent.

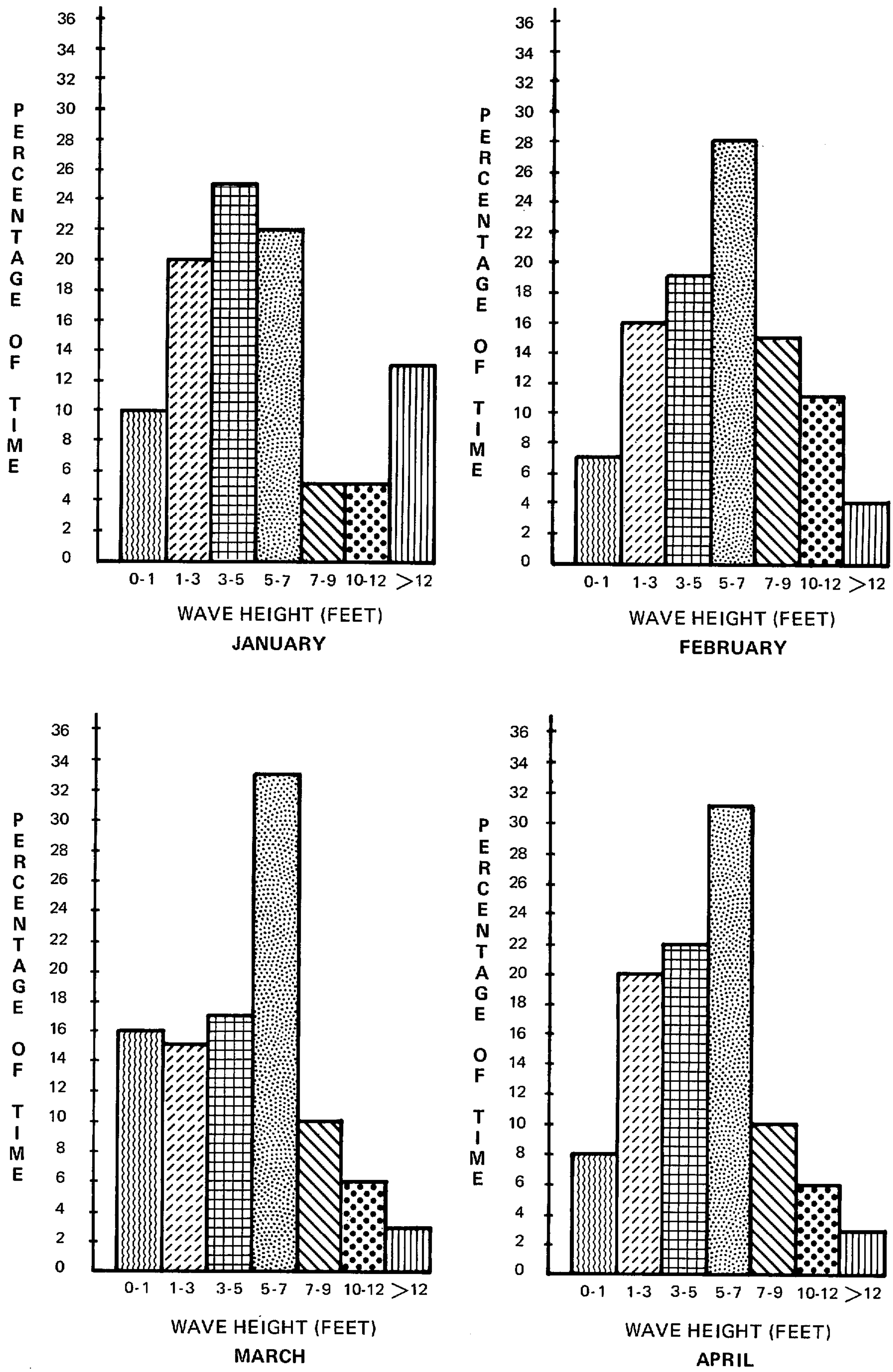
With the increase in winds associated with local fronts and tropical disturbances during September (Figure 66) there is a reversal in the trend to a calmer sea. However, the preponderance of waves, 83 percent, is still less than 7 feet.

Fifty percent of the waves during October (Figure 67) are between 3 and 7 feet. The remaining portion of time is divided 34-16 with the sea state of calm to waves of 3 feet accounting for the former and those larger than 7 feet for the latter figure.

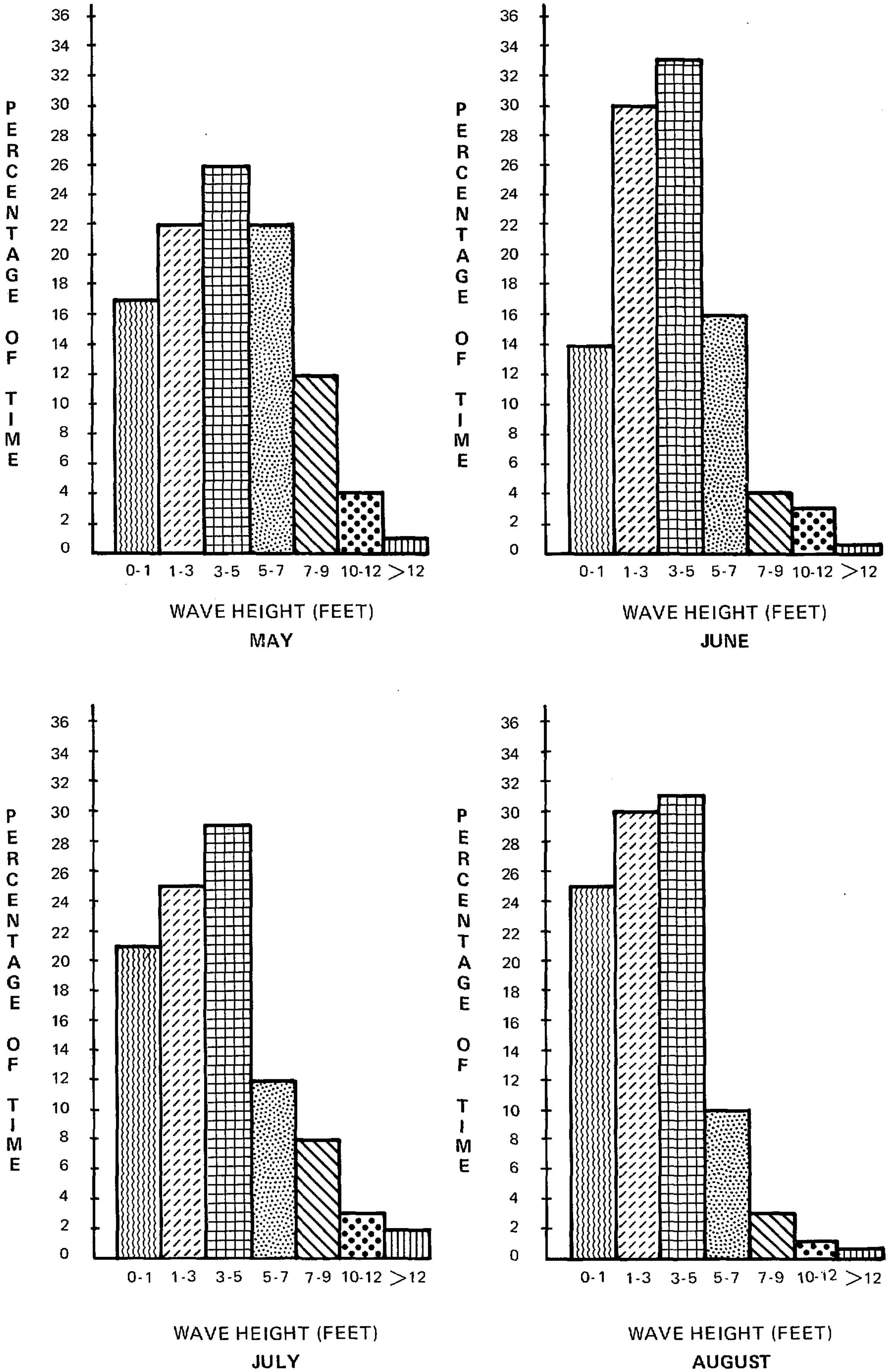
In November (Figure 68) there is a definite increase in frequency of waves greater than 7 feet. The frequency of occurrence of waves larger than 12 feet quadruples from the previous month to 4 percent.

While the frequency of the upper-two classes comprising waves of heights 10-12 feet and greater than 12 feet remains at 4 percent, there is a definite shift to a milder wave climate during December (Figure 69). This trend is notable in the increase in frequency of the lowest two classes of wave heights.

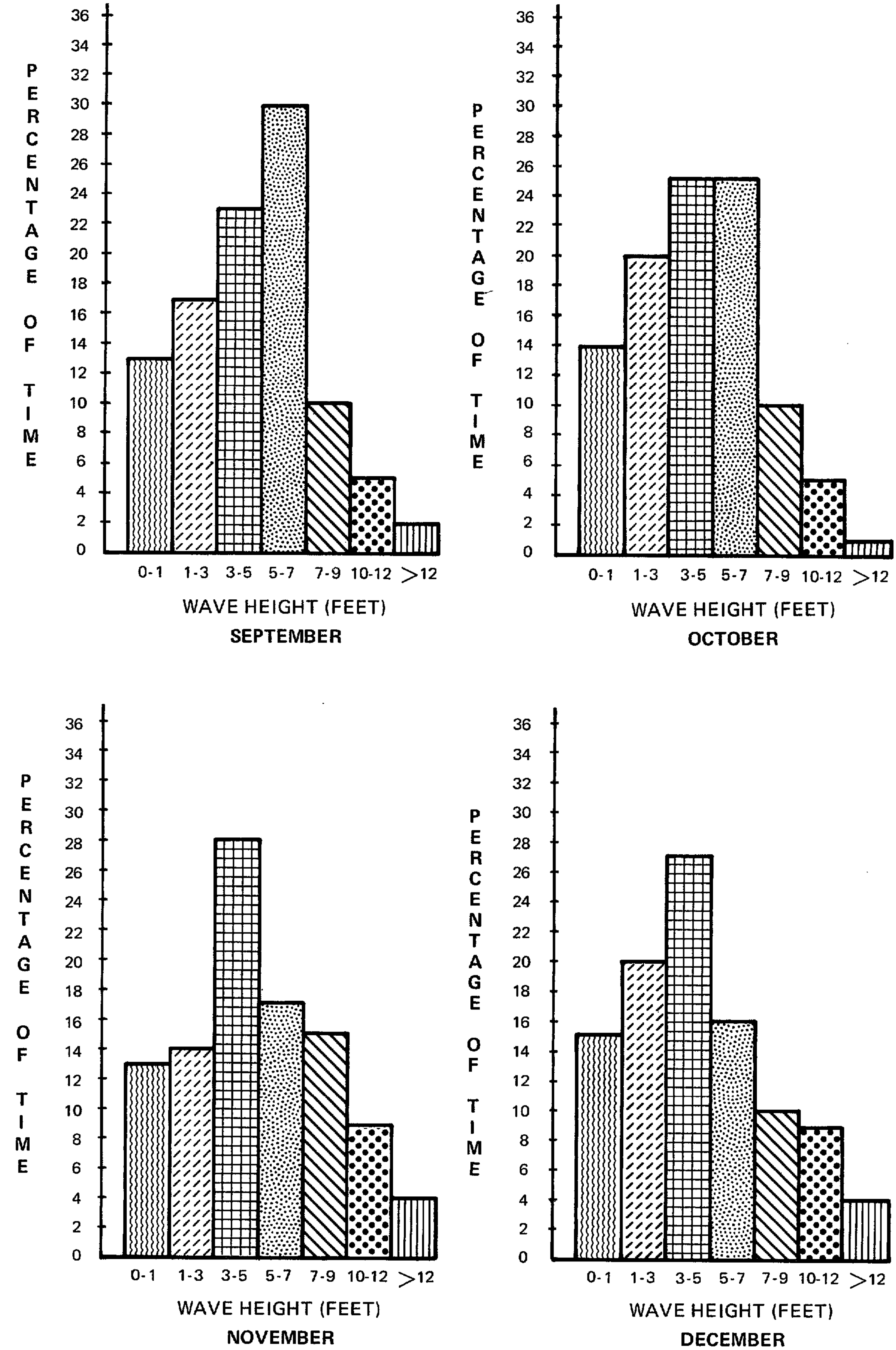
At the present state of technology, waves greater than 12 feet are considered the critical sea state for supertanker-off-loading operations. From the wave statistics presented for the proposed Superport site, waves in excess of 12 feet occur only slightly more than 3 percent of the time. Furthermore, if January, which experiences waves in excess of 12 feet 13 percent of the time, is excluded from the calculations, the frequency percentage for the remaining 11 months is then only 2.25 percent. Combined, the months of January, February, November, and December account for 65 percent of the waves greater than 12 feet.



FIGURES 58, 59, 60, 61. WAVE HEIGHT DISTRIBUTIONS.



FIGURES 62, 63, 64, 65. WAVE HEIGHT DISTRIBUTIONS.



FIGURES 66, 67, 68, 69. WAVE HEIGHT DISTRIBUTIONS.

Wave Refraction

When a wave proceeds into progressively shallower water, it is affected in several ways. If the water depth becomes less than one-half the length of the wave (measured from crest-to-crest or trough-to-trough), the wave begins to "feel" bottom, i.e., friction becomes significant. As the wave enters shallow water, the front of the wave begins to feel bottom which results in its slowing down while the back of the wave is continuing at its original speed. The differential in speed thus produced over the length of the wave causes the wave height to decrease momentarily, followed by an increase continuing until the wave builds so steep that it becomes unstable and breaks. If a long-crested wave travels into shallow water at any angle other than perpendicular to the isobaths, one end of the wave will begin to "feel" bottom before the other. Because "bottom drag" along the wave is encountered at different times, a differential in speed results along the crest of the wave denoted by a "bending" of the wave. This action is referred to as wave refraction.

While stable waves would probably have little effect on the transport of oil in deep water, the refraction of waves warrants attention.

The bathmetry of the shelf area was digitized and represented by a uniform, equilateral grid with sides of 3.28 miles. A design wave that would begin to feel bottom at a depth of 120 feet (the depth of the site for the proposed Superport monobuoy) was selected. A wave of this length (240 feet) corresponding to a wave period of 17.0 seconds, although in itself occurring infrequently, would depict generally what can be expected during refraction of shorter and longer waves.

For this study three specific directions in which waves frequently travel were selected. From the refraction patterns of these three waves, the refraction pattern of waves with orientations intermediate to those used is easily deciphered. Waves traveling offshore were not considered for wave refraction studies simply because, with the increasing depth seaward, the waves would never feel bottom and thus would continue in a straight line.

Figures 70–72 are computer generated refraction diagrams of three 17.0 second, long-crested, linear waves with orientations of 0° (north), 315° (northwest), and 45° (northeast), respectively. The path of the wave crosses the proposed Superport site in each case. The wave rays, or wave orthogonals, shown in the figures are lines that are always perpendicular to the crest of the wave. There is an equal partitioning of energy between the wave orthogonals, i.e., there is a fixed amount of energy represented by the interval between any two orthogonals. A spreading or divergence of the orthogonals signifies a bend in the wave, a dispersal of energy along the wave crest, and a corresponding decrease in the height of the wave. The convergence of orthogonals, likewise, denotes a concentration of energy and an increase in wave height. Theoretically, a crossing of wave orthogonals signifies a wave of infinite height, but in actuality, usually indicates the presence of a caustic. A caustic is caused by waves from different directions, and also possibly differing in height and period, intersecting. This area of intersection, depending on the difference in phases and heights, usually produces "choppy" or "confused" seas.

The tick marks along the wave orthogonals denote the wave crest position every 357 seconds. The tick marks can also be interpreted as being the crest position of every twenty-first wave.

The wave in Figure 70 is traveling due north and, in general, is perpendicular to the isobaths. There is little refraction or shoaling of the waves until they are much closer to shore.

The refraction pattern of a wave oriented toward the northwest (Figure 71) shows the rapid bending as it approaches the barrier islands. A wave will break when it reaches a slope of 1:7, so the wave used in this study will become unsteady and break long before it reaches the islands.

The northwest end of a wave traveling to the northeast (Figure 72) will "feel" bottom and begin to slow down causing a bending of the wave to a more northerly direction. Considerable dispersion along this northern portion of the wave results in a sizable decrease in wave height.

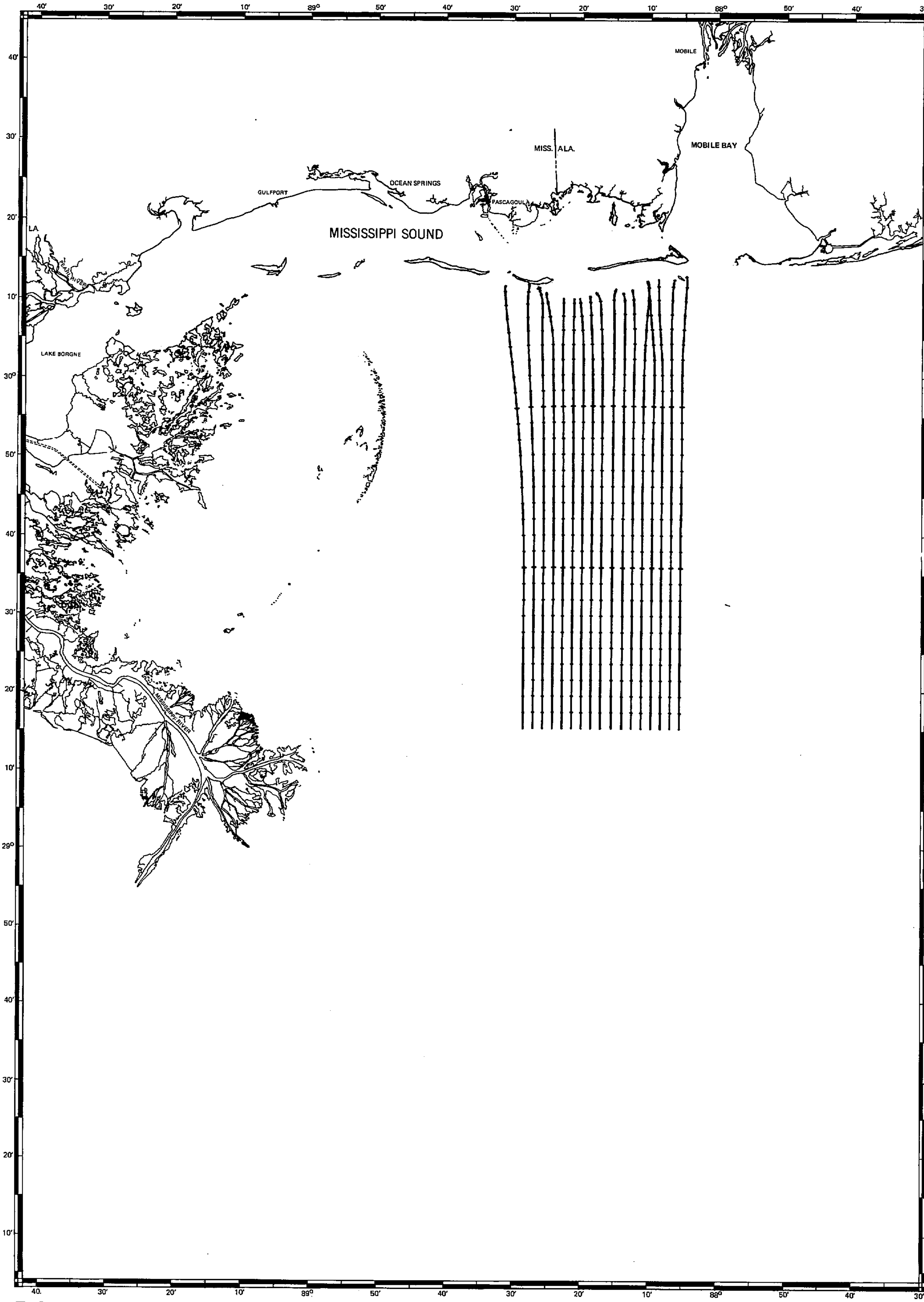


FIGURE 70. WAVE REFRACTION DIAGRAM FOR WAVE ORIENTED 0°.

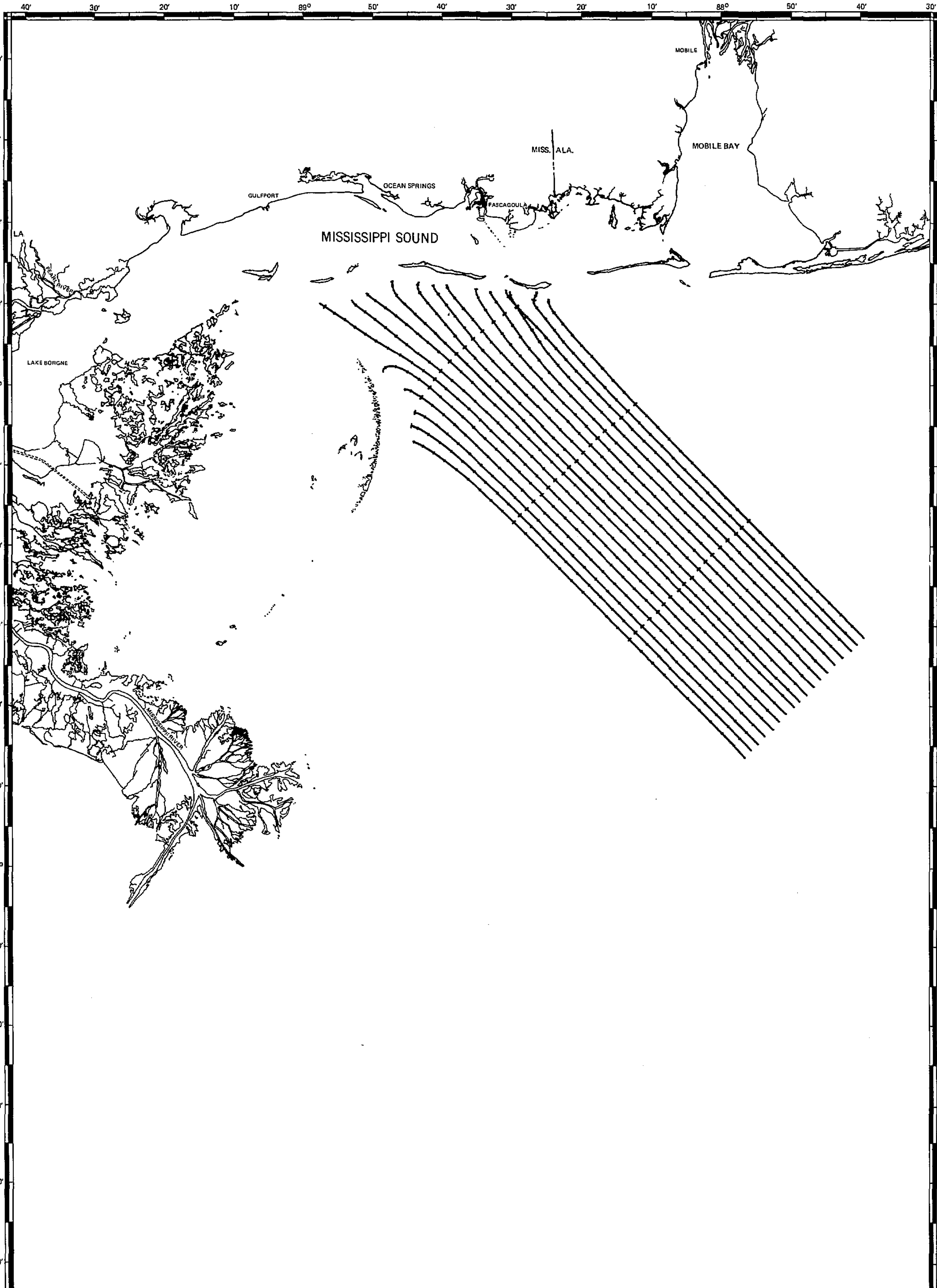


FIGURE 71. WAVE REFRACTION DIAGRAM FOR WAVE ORIENTED 315°.

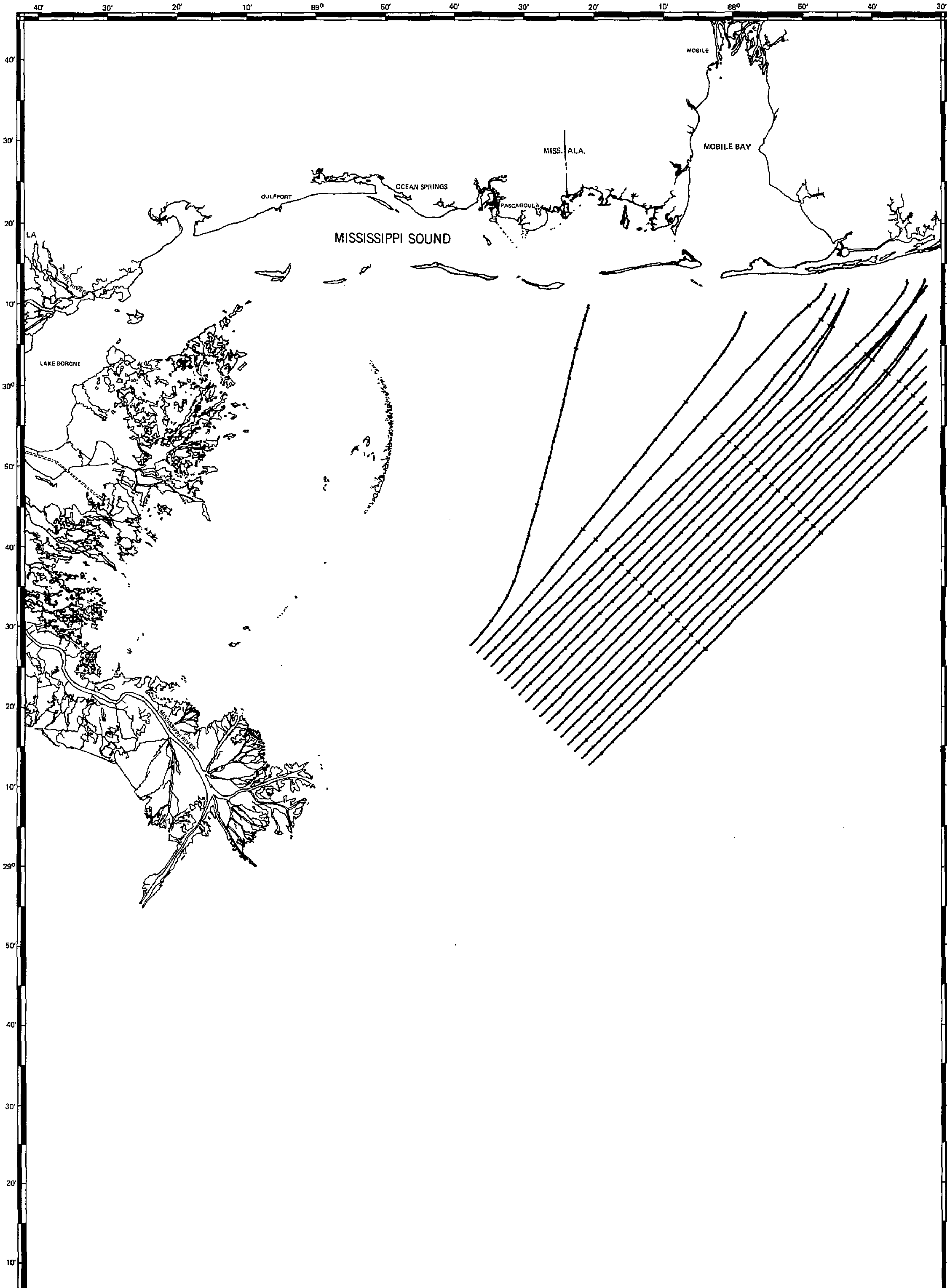


FIGURE 72. WAVE REFRACTION DIAGRAM FOR WAVE ORIENTED 45°.

Water Characteristics of Gulf of Mexico

Deep water entering the Caribbean basin through the Windward Passage between Cuba and Haiti is introduced into the Gulf of Mexico through the Yucatan Straits by the Loop Current. The relatively shallow sill depth of the Yucatan Straits governs, to a large degree, the types of waters passing into the Gulf by preventing the entry of heavier waters located below the sill. The presence of water originating in the Antarctic at the intermediate depths is identifiable by the salinity minimum at 500-1000 meters. Water from great depths of the North Atlantic, characterized by high levels of dissolved oxygen, is also present in waters entering the Gulf. The existence of high-salinity water at a depth of 100 to 200 meters substantiates the contribution of water with an origin at the surface in tropic regions.

The significant distinction between the waters of the east and west Gulf is a direct reflection of the difference in degree of Loop Current influence on the hydrography of the two areas. The hydrography of the east Gulf is dominated by the Loop Current while the west Gulf, less influenced by the Loop Current, expresses a chemistry dictated primarily by river discharges. The chemistry of waters entering the Gulf via rivers is markedly different from the oceanic waters of the open Gulf.

Fluctuations in levels of surface salinity are due to evaporation, precipitation, and mixing with run-off waters from contiguous land areas. Surface salinity, which varies seasonally across the Gulf, is complexed in the east Gulf by the presence of the variable Loop Current and in the west Gulf by highly variable rates of run-off seasonally and annually.

One major distinction between waters of the east and west Gulf lies in the vertical profile of dissolved oxygen. Figure 73 illustrates typical dissolved-oxygen profiles for the east and west Gulf and in the Yucatan and Florida Straits. As should be expected, there is a striking similarity in the oxygen profiles between waters of the east Gulf and the two straits. The east Gulf waters display a secondary oxygen minimum at about 200 meters which apparently is the low-oxygen water from the tropics. The oxygen minimum for west Gulf waters occurs at a greater depth and is broader in extent than waters of the east Gulf. It has been estimated that the difference in oxygen levels between the east and west Gulf is approximately that which is necessary to oxidize all the carbon produced in a three-year period in the euphotic zone. This is strong evidence that the renewal rate of east Gulf waters is three times faster than that of the west Gulf. The waters of the Gulf below 1,500 meters appear to be homogeneous with respect to the level of dissolved oxygen.

In the vicinity of the Mississippi River Delta, surface waters have a dissolved organic carbon concentration of approximately 2.31 mg C/ℓ. Open Gulf waters express a much lower level at 0.74 mg C/ℓ. Waters over the continental shelf remote to the influence of the Mississippi River discharge usually have a concentration near 1.0 mg C/ℓ.

The surface distribution of particulate organic carbon in the Gulf of Mexico is similar to that of dissolved organic carbon with a maximum of 1.911 mg C/ℓ near the Mississippi River Delta decreasing to 0.05 mg C/ℓ in the open Gulf.

Loop Current waters, characterized by salinities of 36.7 ppt at temperatures of 22.5C, are frequently detectable over the continental shelf south of Mississippi. The strong salinity and density gradients apparent in the upper layers of this shelf area during spring and summer are easily correlated with the freshwater discharge from Mississippi River's eastern passes.

Considerable variation in the temperature structure of the water column is apparently caused by advection, local climatic changes, and fluctuations in river discharge. In winter the waters of the outer shelf are isothermal to a depth of 100 meters where a well-developed thermocline exists. A seaward-oriented positive gradient is produced over the shelf during the winter months due to the waters from the rivers being colder and lighter. By early spring the thermocline in outer-shelf waters rises to a depth of approximately 35 meters. The deeper waters, both on the shelf and further out, are considerably colder by mid-summer probably due to advection.

Figure 74 depicts the average temperature, minimum and maximum temperatures recorded at 28 stations located within a five-mile radius of the proposed monobuoy site. The stations were sampled almost monthly over a two-year period. A statistical investigation substantiates the skewness toward low values through the water column as depicted in the illustration. For further clarification the median value was from 0.5 to 2.0 ppt higher than the mean value at every level through the water column. It should be noted that while there is a reduction in range with depth, it is still rather broad. On 13 January 1965 a temperature inversion to a depth of 31 meters was observed. The temperature at a depth of 31 meters was 1.8C warmer than that recorded for the surface.

The mean and extremes of salinity from the same 28 stations used for temperature are depicted in Figure 75. The reduction in range with depth begins quite rapidly below 5 meters. There is a negative skewness in the distribution of salinity to a depth of 15 meters below which the skewness becomes positive. This further implies that the Loop Current waters are at least periodically present over the shelf area.

An inspection of the profile of the mean and extremes of density (σ_t) (Figure 76) shoes there is relatively little variability below 15 meters. This depth appears to be the lower limit of influence by river discharges or run-off.

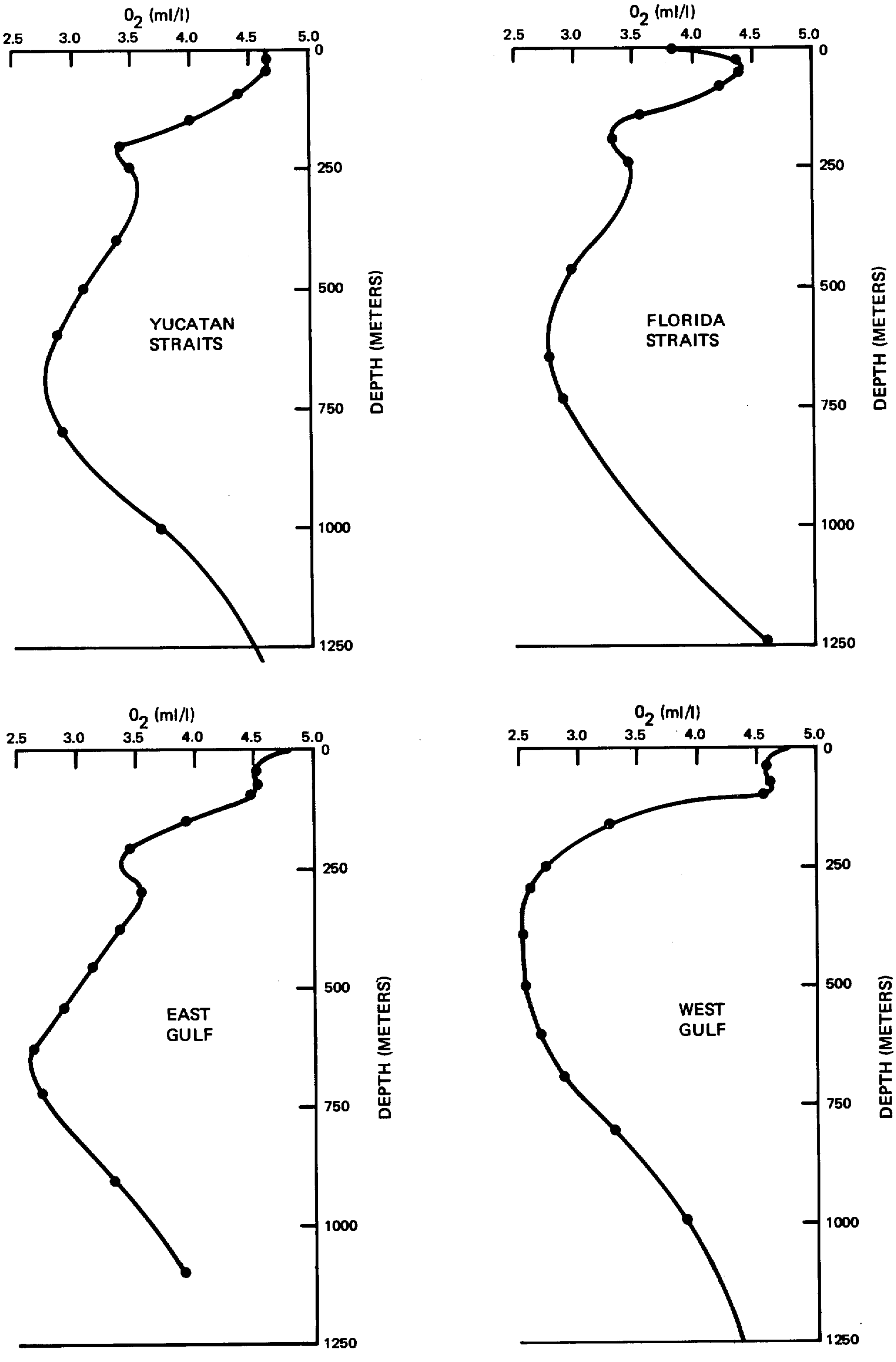


FIGURE 73. DISSOLVED OXYGEN PROFILES, GULF OF MEXICO.

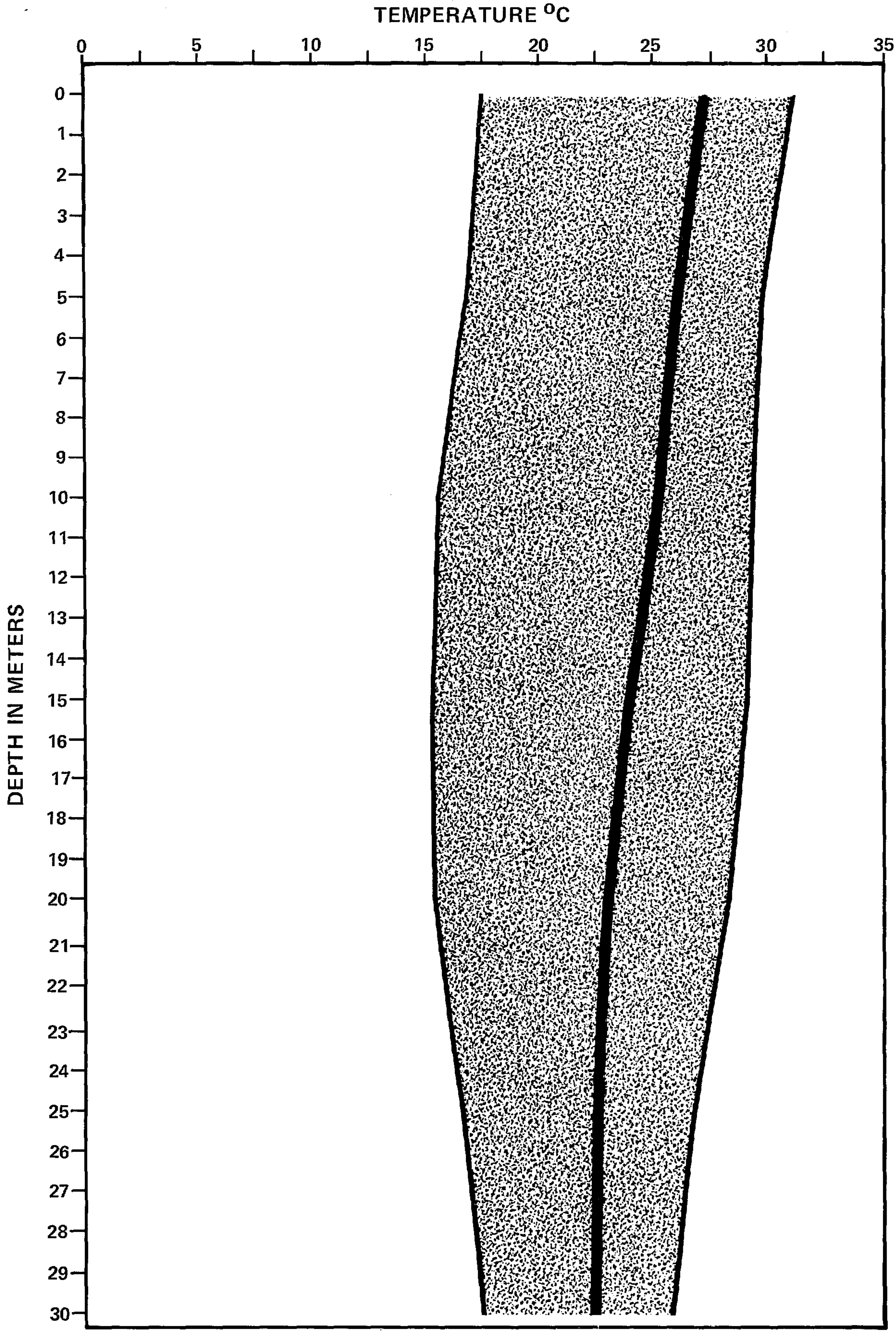


FIGURE 74. WATER TEMPERATURE PROFILE, AVERAGE AND EXTREMES.

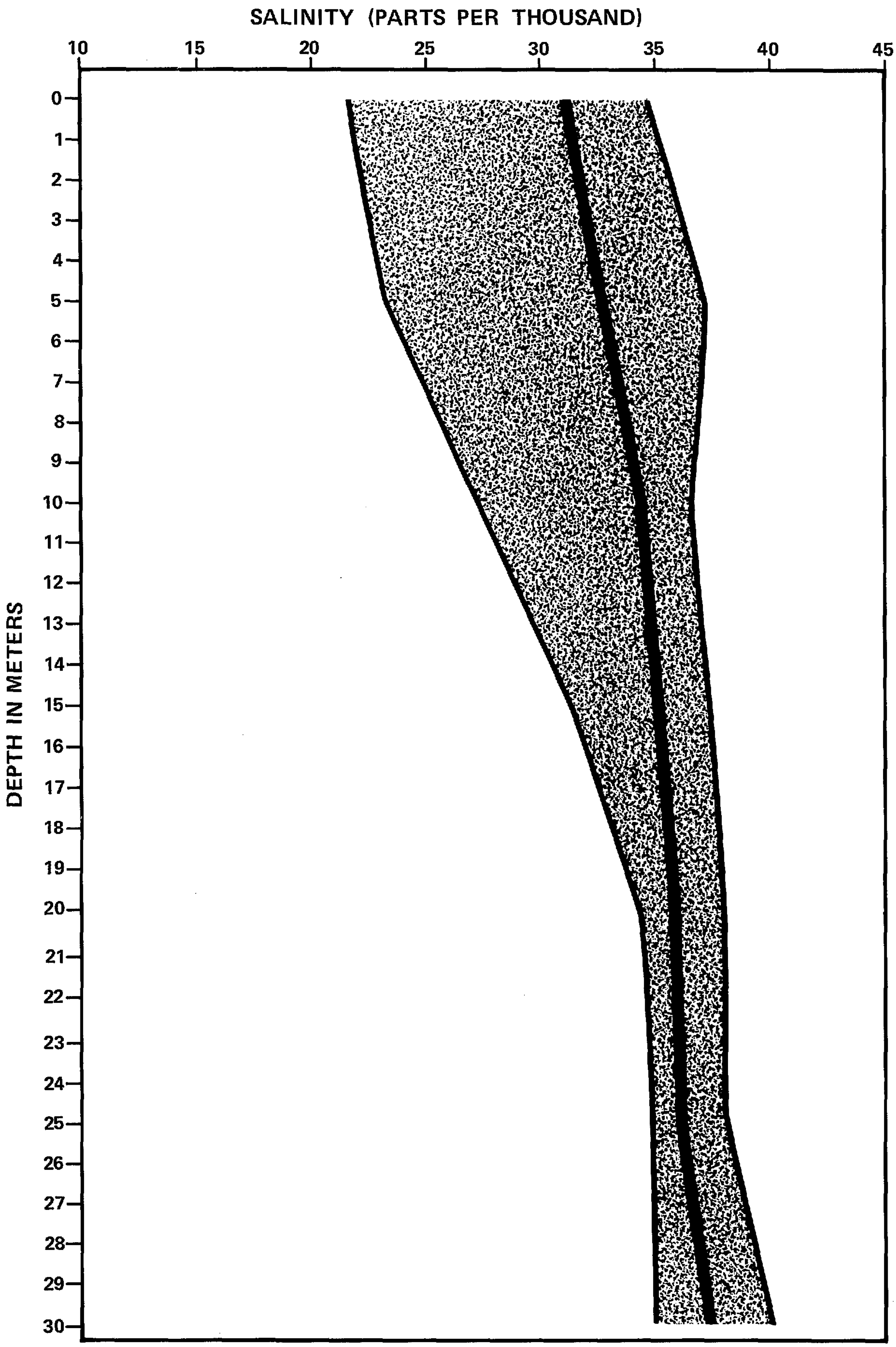


FIGURE 75. SALINITY PROFILE, AVERAGE AND EXTREMES.

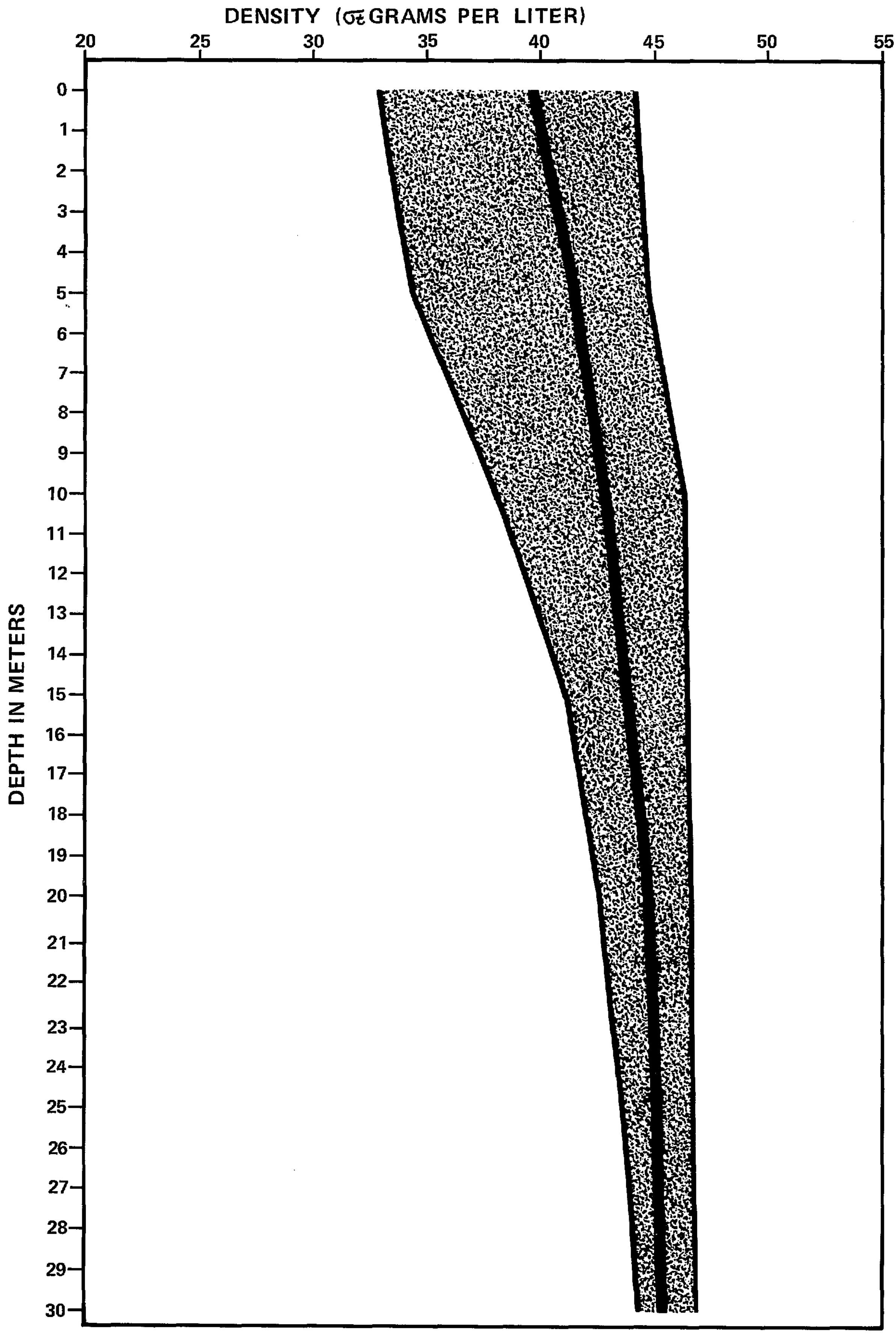


FIGURE 76. DENSITY PROFILE, AVERAGE AND EXTREMES.

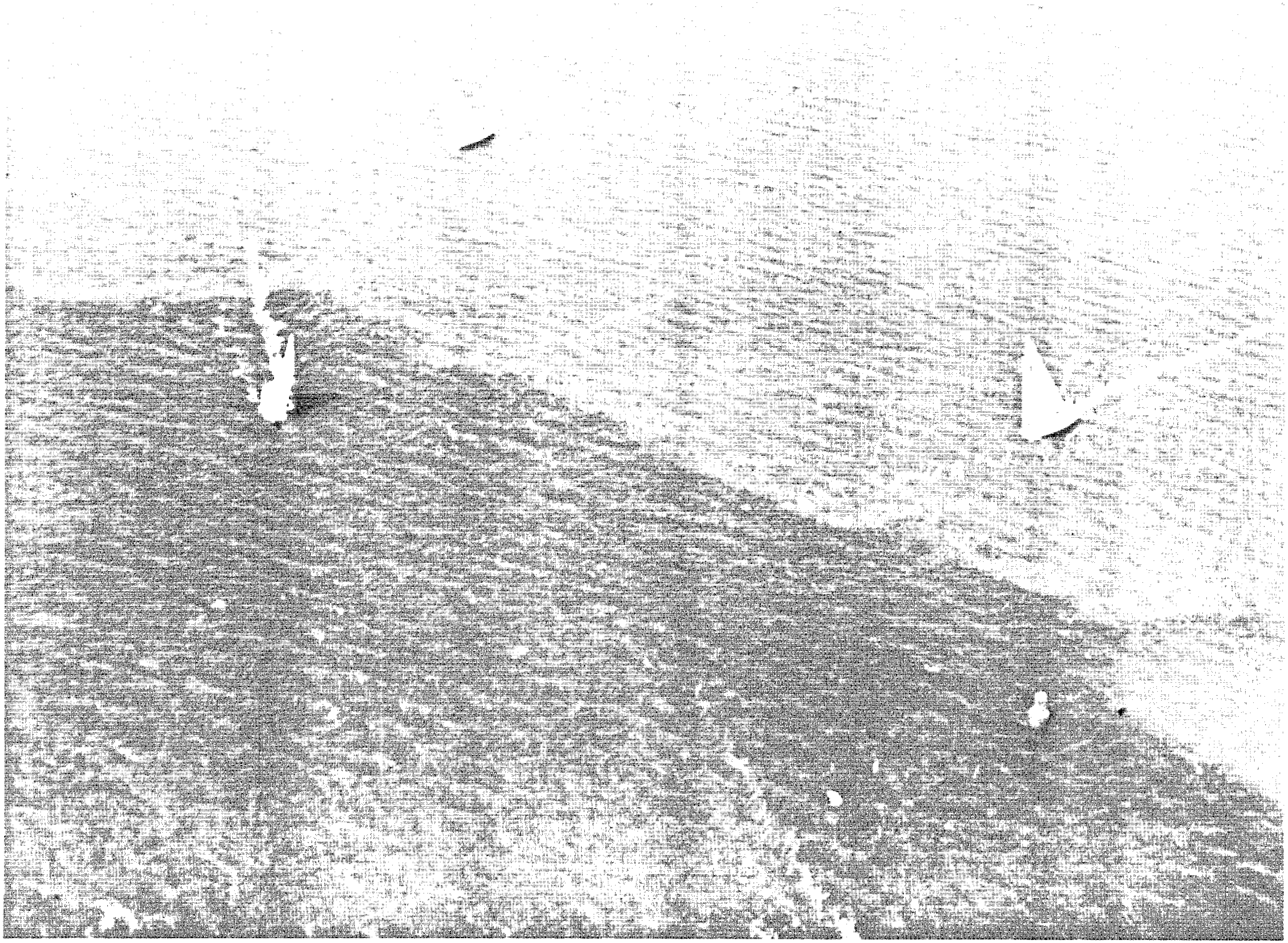


PHOTO 4. CONTRASTING MISSISSIPPI SOUND AND GULF WATERS

Mississippi Sound and Subsystem Circulation

A chain of barrier islands serves to define the southern extent of Mississippi Sound for its entire length. Some of these islands: Dauphin, Petit Bois, Horn, and Ship now comprise a portion of the Gulf Islands National Seashore. The western boundary of the Sound is an indistinguishable region near Grand Island where the Sound merges with Lake Borgne. The shallow, discontinuous shell reefs that extend from Cedar Point, Alabama, to Dauphin Island define the east limit between Mobile Bay and Mississippi Sound.

Mississippi Sound, a part of the "Fertile Fisheries Crescent," is a relatively shallow mixing basin for the fresh water discharged by the river systems and the sea water which enters the Sound through the island passes. Mississippi Sound, a highly productive estuarine system, has a wet surface area of 817 square miles within the boundaries defined. It has an average depth of 9.9 feet at mean low water with an elongated, basin-like configuration of isobaths. The deepest portions of the Sound occur at the western ends of the islands as a result of scouring. The profile of the few natural mainland beaches, in general, indicates a low energy coastline. However, certain segments of the mainland, subject to strong currents and direct attack by waves, show considerable erosional activity. It has been estimated that the offshore chain of islands are migrating westward due to littoral drift at approximately 50 feet per year.

Mississippi Sound is traversed by three major channels maintained by the Corps of Engineers. The Pascagoula Ship Channel, with an authorized depth of 40 feet, extends from south of Petit Bois Island to a point within the Sound where it divides into two branches, one reaching to the mouth of Pascagoula River and the other providing access to Bayou Casotte Industrial Park. If approved, official requests from the Pascagoula Port Authority will authorize deepening the existing channel to a depth of 50 feet.

The Biloxi East Approach Channel, with an authorized depth of 12 feet, begins south of the west end of Horn Island and proceeds on a northward course east of Deer Island into outer Biloxi Bay. In the outer Bay this channel is intersected by the West Biloxi Approach Channel which begins at the Sound's north 12-foot isobath, circumvents Deer Island to the west, and follows the mainland eastward to the point of intersection with the East Biloxi Approach Channel. The resulting single channel continues up Back Bay of Biloxi Bay to Big Lake where it branches and provides access to the Harrison County Industrial Seaway and Biloxi River.

The Gulfport Ship Channel, which begins south of the west tip of Ship Island and extends directly to the Port of Gulfport's Ship Harbor, has an authorized depth of 32 feet. The Intracoastal Waterway, which crosses Mississippi Sound in an east-west direction, requires dredging to 12 feet only at the east and west extremes. This waterway is used primarily by tug and barge traffic.

In the process of providing and maintaining the required channels and waterways, a problem of no small magnitude has developed. It has been a common practice to place "dredge spoil," the material removed for channel construction, parallel to and some distance removed from the channel under construction. With subsequent dredging to maintain or deepen these channels, the parallel ridges of spoil attain a height which seriously alters the normal flow of water. These submerged unmarked weirs, frequently exposed at low tide, are also a hazard to navigation. While this matter has received some attention in recent years, the problem still remains and is growing.

Lake Ponchartrain, which in part drains the highly industrialized and urbanized New Orleans and the rapidly urbanizing northern shoreline and interior by streams and small rivers, flows via the Rigolets and Chef Menteur Pass into Lake Borgne and on to Mississippi Sound. Pearl River, which drains much of the interior of Mississippi, discharges into Lake Borgne just east of Rigolets. The Pascagoula River, which with its tributaries drains much of the eastern and central portion of Mississippi, serves as the artery being developed as the Pat Harrison Waterway. Pascagoula River discharges into Mississippi Sound at Pascagoula, Mississippi.

A portion of the discharge of Mobile Bay, which is the termination of the major drainage systems of the State of Alabama, is forced apparently by density currents to flow into east Mississippi Sound through Grant's Pass. Other independent streams, draining rather large areas of south Mississippi, also empty into the Sound via St. Louis Bay and Biloxi Bay.

The approximately 817-square mile area of Mississippi Sound is the eventual recipient of the effluents via river discharges and direct run-off from 37,750 square miles of land of diversified usage. Since the estuary thus reflects the activities throughout the drainage basins, the water quality of Mississippi Sound is not determined wholly on a local basis.

The general circulation over the shelf south of Mississippi, discussed earlier in this report, reveals a westward flow just south of the islands from southwest of Pensacola, Florida. The prevailing circulation over the shelf influences the circulation and general hydrography of Mississippi Sound. This westward flow, seaward of the islands, forces approximately one-fifth of the lighter Mobile Bay waters into Mississippi Sound through Grant's Pass. It seems reasonable that seasonal and annual changes in the pattern and intensity of the currents over the shelf must also affect the circulation within the Sound. The configuration of offshore islands and currents further suggest that they serve as a barrier that retards the dispersion of the brackish waters from the Sound.

The predominantly diurnal tides of Mississippi Sound with an average range of 1.5 feet are those of the contiguous segment of the Gulf of Mexico that are modified by the barrier islands and the geometry of the Sound. Sustained winds and fluctuating rates of river discharges often further modify the local tides. Northwesterlies that occur frequently during the winter months push the waters out of the Sound, exposing much of the bottom, especially reefs and bars that are otherwise covered. Sustained winds from the south or southeast have the opposite effect of pushing water into the Sound and piling it up along the mainland shore. At times these wind-driven tides attain heights of 5 to 6 feet and cause flooding of low lying areas including the beach highway, U. S. 90, in Harrison County. There is usually a longer period between times of low and high water than between the times of high and low water. Records from tide gauge stations located along the Mississippi coast indicate that the tide wave progresses from east to west through the Sound.

The combined effects of currents and waves from the southeast result in a net westward littoral drift through the Sound. This littoral drift is easily discernible from the longshore transport of sediment. The U. S. Highway 90 storm drains jutting into the Sound in Harrison County, Mississippi, act as groins trapping sand on the east side of the drain pipes and scouring the beach away on the west side. The process produces a scalloped coastline vividly displayed in aerial photographs. The presence of this natural phenomenon which occurs across the breadth of the Sound bears careful attention. Interruption of this "River of Sand" by channelization accompanied by poor disposition of the "dredge spoil" will cause an eventual depletion of sands suitable for beach refurbishment.

Mississippi Sound is subject to rapid changes in both temperature and salinity due to sudden changes in air temperature, evaporation, river discharges, rainfall, and tides. The "wet period" or period of high rates of river discharge occurs from November through June. Tables II-VII show the year and monthly average discharge in cubic feet per second for rivers emptying directly or via bays into the Sound.

Fresh water from the rivers usually flows seaward as a thin surface layer mixing with the higher saline waters below. A recent three-year study found that only during periods of unusually high rates of discharge are the outflows from the rivers observed in an unmixed state seaward of the barrier islands.

Two rivers, the Biloxi and Tchoutacabouffa, draining a total of 513 square miles, empty into Big Lake at the head of Biloxi Bay. A strong vertical discontinuity in salinity in Biloxi Bay detected during periods of high river flow would, by commonly-used guidelines, define the Biloxi Bay estuary as highly stratified. However, during the other periods, especially late spring and early summer, the water column becomes almost homogeneous with respect to salinity in the intermediate segment of this estuary. A one-year study showed this estuary to be predominantly of the partially-mixed type but on occasion it assumes other-type characteristics. A well-defined salinity wedge correlating with the flood stage of the tide was found proceeding up Biloxi Bay under the lighter bay water during several study cruises. Direct-current measurements further revealed the existence of a stratified flow structure on several occasions.

Hydrographic sampling in St. Louis Bay has been too sparse to make any definite statements concerning the physical characteristics of the water, water structure or current patterns. Two rivers, Jourdan and Wolf, with drainage areas of 340 and 380 square miles respectively, discharge into St. Louis Bay. Jourdan River is influenced by tides along its entire length making accurate gauging of its flow a difficult and costly task. It is presently not gauged. Flow records for Wolf and Jourdan Rivers are incomplete as shown in Tables V and VI. The two rivers discharging on opposite sides of the shallow bay complicate the circulation by their outflows varying in both rate and time relative to each other.

Pearl River, with an average flow of 8,582 cubic feet per second and a record maximum of 88,200 CFS, discharges into the relatively shallow Lake Borgne, the west boundary of Mississippi Sound. Most of the Pearl River outflow continues seaward around Grand Island and through Cat Island Channel. Because of the maintenance of a regime of low salinity water in this area that deters immigration of predators requiring higher salinity, the area is considered desirable for establishment of oyster reefs. However, prolonged exposure of the reefs to extremely low salinity caused by continued high rates of river discharge results in extensive oyster mortality.

There is a definite negative salinity gradient from east to west through Mississippi Sound. There is, of course, a positive salinity gradient seaward from the mainland. Salinity levels observed through the water column taken from near the mainland to the island passes have ranged from fresh water to 35.5 ppt.

The temperature structure of the Sound and bays generally shows a positive gradient seaward during winter with the reverse being true for summer. Temperatures usually decline with depth through the water column with isothermal situations being common in the shallower areas. Cold fronts passing over the Sound cause pronounced temperature inversions. Strong thermoclines exist near river mouths during periods of high river flow.

Mississippi Sound and bays receive an estimated total of 9,920,737 tons of sediment annually from only a portion of the streams contributing waters to the Sound. The fine silts, clays, and fine organic matter remaining in suspension largely account for the turbid conditions almost characteristic of Sound waters. The anions of the salts in sea water combine with the cations of the clay particles and flocculate out of suspension. The fine silts and clays of the relatively shallow Mississippi Sound are resuspended during stormy weather when waves attain heights that permit them to "feel" bottom.

The surface isotherm and isohaline charts (Figures 77-82) of east Mississippi Sound in the vicinity of Pascagoula, Mississippi, were furnished by a presently on-going but yet incomplete study of Sound circulation. While these figures do not represent the final verified form of the data, any changes would be of a minor nature and thus will not significantly alter the patterns as depicted here.

The warmer river water (Figure 77) is seen moving to the south-west around the southern extent of the dredge spoil ridges. The discharge from west Pascagoula River moves westward along the mainland to where the coastline indicates an inflection point in the curvature. At this point, the flow turns south and on 23 May 1973, during a rising tide, shows a continued eastward deflection.

The isohalines (Figure 78) constructed from data taken the same date clearly show a turn to the southwest. The pattern of isohalines extending from the west is in agreement with the pattern of isotherms. The relatively high salinities near the mouth of the river reflect a period of relatively low river flow.

The surface temperature of 14 June 1973 (Figure 79) illustrates the seaward flow of lighter, fresher water from the west Pascagoula River. A negative temperature gradient is oriented seaward.

A tongue of higher salinity water (Figure 80) is shown extending into the Sound through Horn Island Pass during 26 June 1973. The close proximity of the 9.0 ppt isohaline to the river mouth again reflects a period of relatively small river outflow. Northwest of the tip of the "tongue" is a configuration of isohalines that indicates a westward deflection of the discharge from east Pascagoula River.

The configuration of isotherms for 26 June 1973 (Figure 81) implies a flow first southward then eastward from the west mouth of the river. A sharp turn to the west by the east river outflow just south of the exposed ridge of dredge spoil is clearly shown. The surface temperature declines seaward.

The westward deflection of the lighter but mixed river outflow just south of the exposed line of dredge spoil is illustrated in the pattern of isohalines of Figure 82. An arm of higher salinity water is seen intruding into the Sound through Horn Island Pass. A cell of lower salinity water is located near the east end of Horn Island. A positive gradient exists from east to west across Petit Bois Pass, and is a semi-permanent feature caused by seaward outflow of a portion of the Mobile Bay water which enters Mississippi Sound through Grant's Pass.

Figure 83 is a conceptual depiction of the tide-dominated currents of east Mississippi Sound. The currents in the passes between islands have been recorded at speeds in excess of 1.5 mph. It should be further noted that these currents have been observed to be strongest below mid-water depth on a rising tide and strongest at the surface on a falling tide.

A strong interface characterized by strong gradients of salinity, temperature, pH, and dissolved oxygen has been frequently observed at a depth of 8 to 12 feet in the waters of the Pascagoula Ship Channel. Salinity increases markedly over a distance of 1 to 2 feet. The temperature gradient is less pronounced but coincides with that of salinity. Dissolved oxygen drops to very low levels and on several occasions to levels too low to measure *in situ*, i.e., less than .02 parts per million. This well-defined interface is restricted to the waters of the channel and those waters immediately adjacent.

Channel construction permits the intrusion of heavier, more saline waters into Mississippi Sound that would otherwise be restrained by the natural bottom bathymetry. The heavier water moves up the channel across the Sound as a bottom-oriented salinity wedge. This salt wedge continues up the Pascagoula River and its presence has been detected 20 miles upriver from the mouth.

Figures 84 and 85, reconstructed from a recent three-year study, show the trends in levels of certain physical and chemical parameters with time. The charts were constructed from averages derived from pooling data from several stations in rather close proximity. The averages were computed for surface and near-bottom waters. River-discharge rates for the Pascagoula River during the study period are also illustrated as a frequency polygon.

Temperature (Figure 84) of surface waters from the mainland to mid-Sound ranged from 8.3C in January to 30.9C in August. Maximum vertical difference in temperature between surface and bottom waters was 1.5C. Surface-temperature extremes recorded for the south half of the Sound (Figure 85) were 8.2C in December and 31.8C in July. Temperature extremes for the bottom waters were 9.5C and 30.1C recorded in January and August, respectively.

Surface salinities for the cross section of the Sound ranged from 0.0 to 33.3 ppt. Salinity extremes for bottom waters were 6.0 and 35.5 ppt. The drop in salinity levels, as should be expected, correlates highly with the season and rate of river discharge.

Levels of dissolved oxygen decline rapidly with depth in the lower Pascagoula and Escatawpa Rivers to the point of anoxic conditions. This situation has been attributed to the heavy oxygen-demanding effluent discharging into the two rivers. Some steps intended to correct this undesirable situation have recently been taken.

Dissolved-oxygen levels ranged from 5.88 to 13.05 ppm in the north half of Mississippi Sound. The latter figure was observed during an obvious phytoplankton bloom. The oxygen levels for the south half of the Sound were similar to those of the north half with the normal highs corresponding to saturation values at low temperatures.

Peak nitrate values occurred during May in the north half of the Sound. The greatest nitrate levels are found near bottom. Nitrate levels diminish seaward.

The trend line for inorganic phosphate is quite irregular attributed to the periodic activity of the various sources. Inorganic phosphate extremes for the transect of Mississippi Sound seaward from Pascagoula were 0.25 micro-gram atoms per liter to 5.06 μga/ℓ.

The peak levels of total phosphate occurred in May and were greater in the surface layer than in the bottom layer of water. Total-phosphorus concentrations throughout the Pascagoula River estuarine area reflect heavy pollution of the system. Of 315 samples, only 7 percent showed less than 2 μga/ℓ of total phosphate.

As mentioned previously, some steps have been taken to correct this situation; however, the problem still exists and will require additional effort.

TABLE II. Discharge, Pascagoula River at Merrill, Mississippi.
Monthly Averages in Cubic Feet per Second.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1951	2245.0	2290.0	5945.0	8934.0	18830.0	16530.0	30430.0	3561.0	3457.0	2962.0	1811.0	2338.0
1952	1659.0	2066.0	6777.0	5446.0	11100.0	13180.0	9411.0	7264.0	3091.0	1872.0	1854.0	1601.0
1953	896.0	1338.0	3317.0	9014.0	15700.0	22160.0	14210.0	27540.0	3242.0	5618.0	3225.0	2193.0
1954	1137.0	1799.0	23120.0	8997.0	8527.0	7820.0	14060.0	5473.0	2109.0	2793.0	1177.0	885.0
1955	936.0	1082.0	1598.0	5965.0	10680.0	4671.0	19110.0	1083.0	2142.0	3320.0	6374.0	1428.0
1956	1111.0	1268.0	2961.0	2328.0	21340.0	22490.0	11210.0	2926.0	2876.0	4858.0	1995.0	1280.0
1957	1417.0	1128.0	3868.0	2659.0	4180.0	4971.0	13270.0	6147.0	2672.0	3105.0	1606.0	11000.0
1958	10540.0	18340.0	12750.0	12660.0	16690.0	23510.0	11270.0	16040.0	5937.0	13760.0	6973.0	10230.0
1959	4577.0	2784.0	3753.0	8067.0	16910.0	10790.0	13060.0	5800.0	18010.0	5944.0	4282.0	3798.0
1960	8314.0	10550.0	6743.0	10820.0	19320.0	17850.0	17430.0	13560.0	2262.0	2147.0	5355.0	3220.0
1961	2653.0	4058.0	3143.0	9929.0	44520.0	47600.0	38540.0	4906.0	8517.0	11130.0	5341.0	5319.0
1962	2498.0	11990.0	45210.0	31900.0	16990.0	11850.0	20940.0	13260.0	5527.0	2568.0	2561.0	1654.0
1963	1887.0	2094.0	2250.0	8842.0	9265.0	10150.0	3049.0	1679.0	1517.0	1653.0	1318.0	1224.0
1964	763.0	914.0	2410.0	7414.0	7876.0	27930.0	30140.0	13010.0	3268.0	4961.0	3332.0	1541.0
1965	6055.0	3657.0	17330.0	14850.0	24530.0	15730.0	7065.0	2625.0	2657.0	2651.0	3566.0	2627.0
1966	2385.0	1529.0	3910.0	11210.0	50030.0	24680.0	9554.0	14370.0	3484.0	2655.0	3723.0	2323.0
1967	2455.0	3344.0	4294.0	8836.0	9685.0	5068.0	4434.0	8480.0	2535.0	2780.0	2711.0	2100.0
1968	1371.0	2097.0	19770.0	14040.0	5496.0	9948.0	11300.0	6273.0	2147.0	1562.0	1801.0	1586.0
1969	1065.0	1601.0	10750.0	9707.0	9899.0	15710.0	32610.0	8558.0	2322.0	2699.0	3672.0	1906.0
1970	1421.0	1431.0	3938.0	7196.0	7509.0	14680.0	8452.0	5187.0	2356.0	2964.0	4446.0	2375.0
1971	6129.0	3746.0	6887.0	11970.0	17230.0	35140.0	13340.0	12690.0	3668.0	4021.0	5173.0	5541.0
1972	2504.0	2236.0	24640.0	27930.0	22650.0	16750.0	7845.0	9330.0	2421.0	2570.0	1674.0	1172.0

TABLE III. Discharge, Biloxi River at Wortham, Mississippi.
Monthly Averages in Cubic Feet per Second.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1953	6.0	18.8	257.0	219.0	558.0	248.0	310.0	59.7	146.0	116.0	142.0	21.1
1954	4.3	109.0	498.0	128.0	69.6	96.7	81.0	12.7	9.8	100.0	7.0	5.3
1955	8.6	16.1	86.0	325.0	373.0	34.1	724.0	61.7	10.8	130.0	410.0	18.4
1956	11.1	16.7	53.2	60.6	201.0	246.0	55.8	7.9	311.0	97.5	29.6	237.0
1957	144.0	34.7	459.0	87.6	66.5	151.0	237.0	121.0	52.5	12.9	15.8	410.0
1958	107.0	346.0	181.0	356.0	189.0	470.0	197.0	407.0	232.0	430.0	171.0	223.0
1959	46.6	22.3	24.1	111.0	483.0	256.0	270.0	267.0	587.0	371.0	171.0	272.0
1960	352.0	119.0	92.2	298.0	417.0	194.0	323.0	206.0	7.8	93.1	279.0	231.0
1961	53.1	33.0	33.9	245.0	878.0	820.0	338.0	95.2	312.0	201.0	141.0	483.0
1962	50.7	379.0	652.0	372.0	222.0	191.0	122.0	13.4	38.0	21.9	29.5	26.0
1963	6.8	16.8	56.9	185.0	247.0	95.2	24.0	29.9	7.4	94.3	40.7	14.9
1964	1.9	10.1	92.7	400.0	166.0	274.0	534.0	98.9	67.3	84.5	190.0	52.4
1965	37.8	96.6	226.0	287.0	356.0	238.0	40.1	34.2	160.0	63.9	138.0	152.0
1966	89.8	94.6	156.0	509.0	870.0	547.0	211.0	199.0	23.8	34.2	96.1	16.0
1967	18.3	17.9	65.3	342.0	186.0	41.9	75.7	34.9	26.2	14.7	99.1	169.0
1968	114.0	89.0	431.0	155.0	63.6	68.3	46.3	18.1	33.2	14.9	43.6	62.2
1969	4.2	27.0	220.0	286.0	204.0	453.0	307.0	70.9	7.4	13.6	235.0	32.3
1970	20.2	22.8	106.0	179.0	219.0	557.0	122.0	121.0	154.0	114.0	209.0	62.1
1971	229.0	60.5	292.0	202.0	386.0	254.0	55.0	71.0	25.8	132.0	150.0	300.0
1972	20.2	33.3	281.0	721.0	329.0	293.0	67.1	386.0	16.1	21.2	15.3	5.4

TABLE IV. Discharge, Tchoutacabouffa River at Tuxachanie Creek.
Monthly Averages in Cubic Feet per Second.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1953	6.9	14.8	210.0	169.0	346.0	210.0	213.0	46.6	216.0	137.0	69.9	14.4
1954	5.0	46.8	372.0	72.8	31.8	64.9	31.9	9.1	5.5	25.4	4.5	5.3
1955	6.3	9.7	65.5	245.0	393.0	25.3	908.0	32.8	8.5	138.0	425.0	24.2
1956	35.0	14.8	60.3	91.4	211.0	282.0	54.7	8.7	153.0	102.0	25.1	246.0
1957	221.0	33.2	462.0	72.4	49.6	142.0	330.0	237.0	66.3	15.3	15.2	987.0
1958	126.0	347.0	165.0	304.0	177.0	574.0	190.0	612.0	197.0	660.0	264.0	186.0
1959	34.2	22.5	23.9	66.6	429.0	267.0	243.0	209.0	583.0	436.0	327.0	277.0
1960	478.0	108.0	64.3	357.0	341.0	220.0	300.0	246.0	10.2	56.9	398.0	266.0
1961	38.6	19.4	37.7	204.0	757.0	557.0	401.0	114.0	311.0	134.0	316.0	479.0
1962	71.5	355.0	487.0	354.0	270.0	139.0	85.6	11.0	184.0	52.2	32.3	48.7
1963	37.6	25.0	76.6	229.0	266.0	115.0	15.2	13.2	15.2	126.0	61.4	29.4
1964	5.0	13.4	127.0	465.0	173.0	214.0	709.0	81.1	13.0	94.0	301.0	197.0
1965	184.0	105.0	201.0	360.0	337.0	386.0	55.4	68.5	230.0	78.5	183.0	313.0
1966	123.0	36.4	127.0	453.0	732.0	466.0	199.0	157.0	36.6	34.9	116.0	56.8
1967	24.0	29.6	59.2	341.0	180.0	38.1	100.0	14.8	26.0	11.9	68.0	240.0
1968	195.0	120.0	277.0	113.0	53.4	52.7	50.2	24.1	9.6	12.3	15.6	40.0
1969	5.4	29.7	218.0	306.0	186.0	445.0	239.0	76.0	7.5	57.7	487.0	32.0
1970	19.4	21.8	107.0	185.0	244.0	381.0	109.0	73.6	139.0	266.0	288.0	99.9
1971	362.0	78.8	333.0	193.0	379.0	244.0	58.8	32.0	56.7	112.0	125.0	472.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE V. Discharge, Wolf River near Lyman, Mississippi.
Monthly Averages in Cubic Feet per Second.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1965	332.0	307.0	828.0	854.0	1016.0	480.0	151.0	57.4	75.5	112.0	253.0	306.0
1966	185.0	232.0	384.0	1193.0	2356.0	1142.0	406.0	251.0	103.0	152.0	262.0	235.0
1967	160.0	135.0	277.0	716.0	560.0	211.0	352.0	306.0	107.0	67.4	166.0	116.0
1968	74.3	105.0	881.0	601.0	248.0	422.0	280.0	122.0	149.0	108.0	60.2	197.0
1969	66.2	150.0	503.0	522.0	352.0	841.0	917.0	252.0	66.1	273.0	634.0	219.0
1970	94.8	125.0	351.0	454.0	540.0	995.0	336.0	273.0	486.0	255.0	342.0	164.0
1971	453.0	212.0	654.0	532.0	838.0	699.0	235.0	244.0	91.6	332.0	458.0	736.0

TABLE VI. Discharge, Jourdon River at Santa Rosa, Mississippi.
Monthly Averages in Cubic Feet per Second.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1964	10.7	21.0	193.0	719.0	236.0	425.0	963.0	141.0	64.7	118.0	162.0	146.0
1966	210.0	201.0	358.0	415.0	641.0	2.6	65.8	37.1	52.4	77.5	52.1	144.0

TABLE VII. Discharge, Pearl River near Bogalusa, Louisiana.
Monthly Averages in Cubic Feet per Second.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
1951	3215.0	2881.0	5287.0	10680.0	24870.0	15940.0	29690.0	6745.0	2946.0	2726.0	2049.0	1914.0
1952	1529.0	1710.0	5834.0	4300.0	7671.0	8912.0	7222.0	4519.0	2673.0	1773.0	1706.0	1440.0
1953	1188.0	1394.0	2240.0	7164.0	15150.0	27880.0	10380.0	36930.0	5618.0	3901.0	3574.0	2064.0
1954	1389.0	1690.0	8793.0	5636.0	7540.0	5274.0	9373.0	10090.0	2401.0	2424.0	1514.0	1246.0
1955	1408.0	1323.0	1713.0	6995.0	14960.0	10130.0	27200.0	6955.0	3374.0	3982.0	4201.0	1619.0
1956	1343.0	1424.0	2934.0	2174.0	26470.0	24230.0	21940.0	4412.0	3776.0	2046.0	1770.0	1423.0
1957	1343.0	1394.0	3463.0	3800.0	7272.0	8147.0	22800.0	5473.0	3700.0	5646.0	2252.0	3270.0
1958	5192.0	16150.0	16780.0	10550.0	12890.0	19220.0	11480.0	25650.0	7983.0	10390.0	6555.0	5004.0
1959	5352.0	2915.0	3808.0	8084.0	18860.0	10510.0	10860.0	7928.0	9046.0	3288.0	3006.0	2656.0
1960	3177.0	4437.0	6988.0	11500.0	20910.0	24480.0	9473.0	9945.0	2265.0	1852.0	4295.0	2388.0
1961	2059.0	2062.0	2390.0	7394.0	22830.0	38550.0	32270.0	4590.0	6145.0	10090.0	4514.0	3651.0
1962	2127.0	12560.0	35690.0	40220.0	21450.0	14390.0	24230.0	11480.0	4662.0	2795.0	2606.0	1996.0
1963	1991.0	1968.0	2151.0	6034.0	7641.0	8999.0	3214.0	1926.0	1651.0	2234.0	1917.0	1458.0
1964	1110.0	1233.0	2289.0	6009.0	5849.0	27820.0	25660.0	18590.0	2568.0	4684.0	3351.0	2147.0
1965	9023.0	3074.0	17820.0	8460.0	21110.0	18140.0	10300.0	2376.0	2028.0	2008.0	2454.0	3412.0
1966	3360.0	1923.0	2739.0	11310.0	34240.0	16860.0	8085.0	19960.0	4407.0	2471.0	2723.0	2532.0
1967	2197.0	2825.0	2972.0	4821.0	66740.0	4764.0	3927.0	10530.0	4891.0	3457.0	2197.0	2209.0
1968	1527.0	1702.0	12220.0	23850.0	6852.0	10960.0	15370.0	11380.0	3438.0	2309.0	2274.0	2071.0
1969	1402.0	1447.0	8578.0	7778.0	8396.0	14370.0	26300.0	11340.0	1910.0	1564.0	2352.0	1766.0
1970	1391.0	1298.0	2390.0	7881.0	4346.0	13205.0	10292.0	9905.0	2850.0	2076.0	2657.0	1945.0
1971	5288.0	3858.0	4052.0	9044.0	11360.0	32450.0	11810.0	22610.0	4178.0	4084.0	6403.0	6400.0
1972	2885.0	2322.0	27860.0	30830.0	20120.0	14950.0	6409.0	9061.0	2562.0	2555.0	2331.0	1867.0

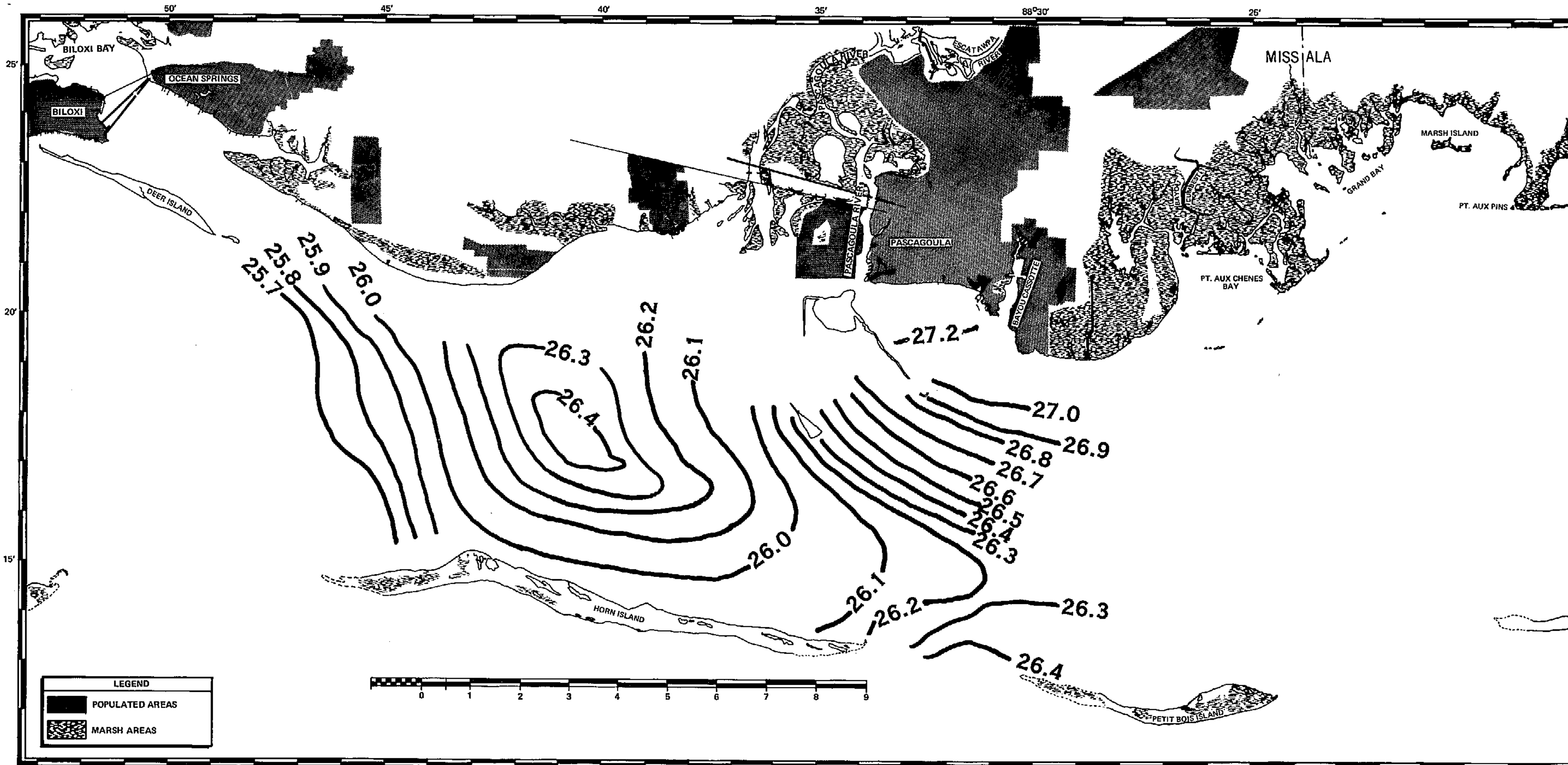


FIGURE 77. SURFACE TEMPERATURE, MISSISSIPPI SOUND, 23 MAY 1973.

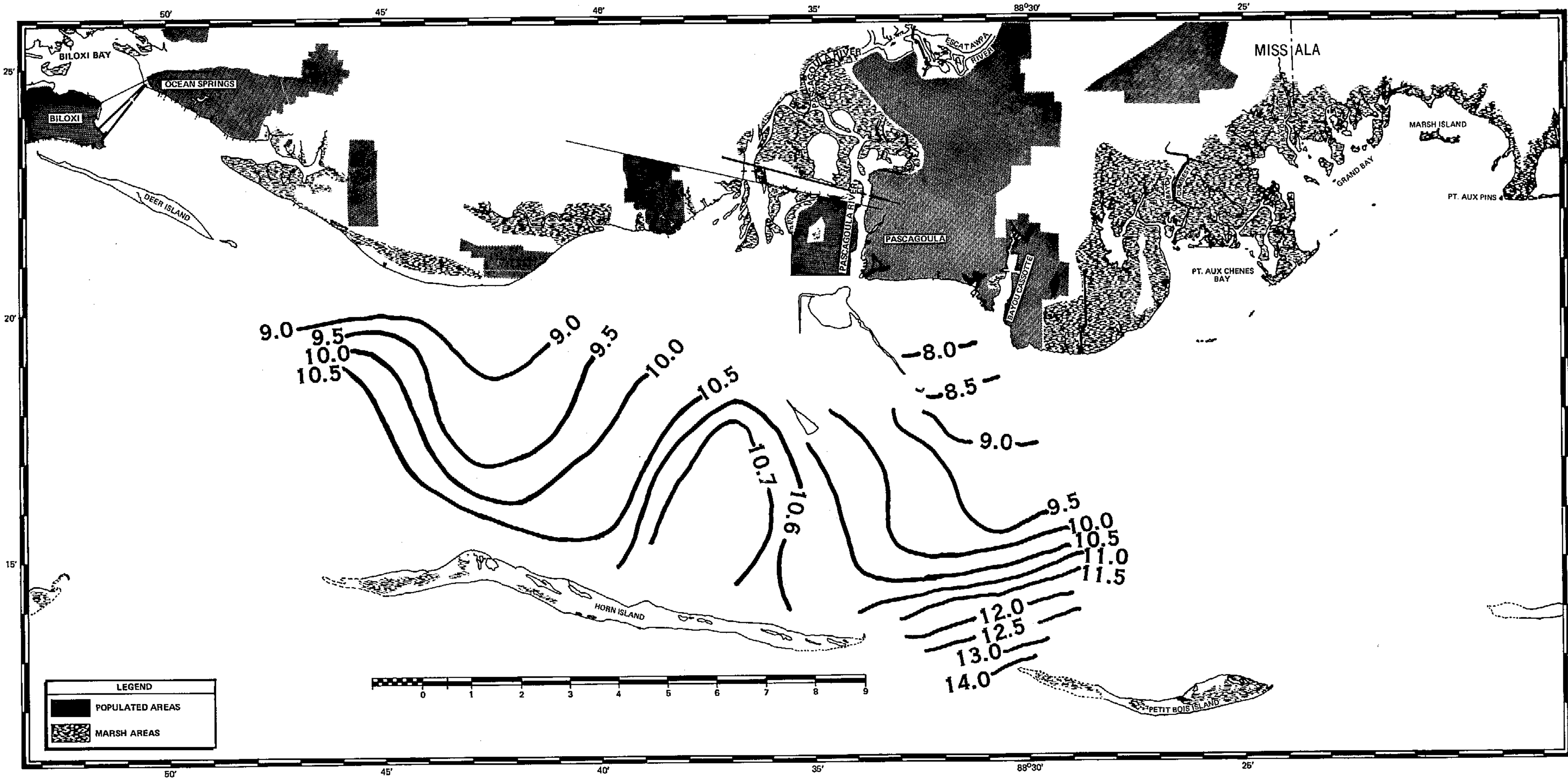


FIGURE 78. SURFACE SALINITY, MISSISSIPPI SOUND, 23 MAY, 1973.

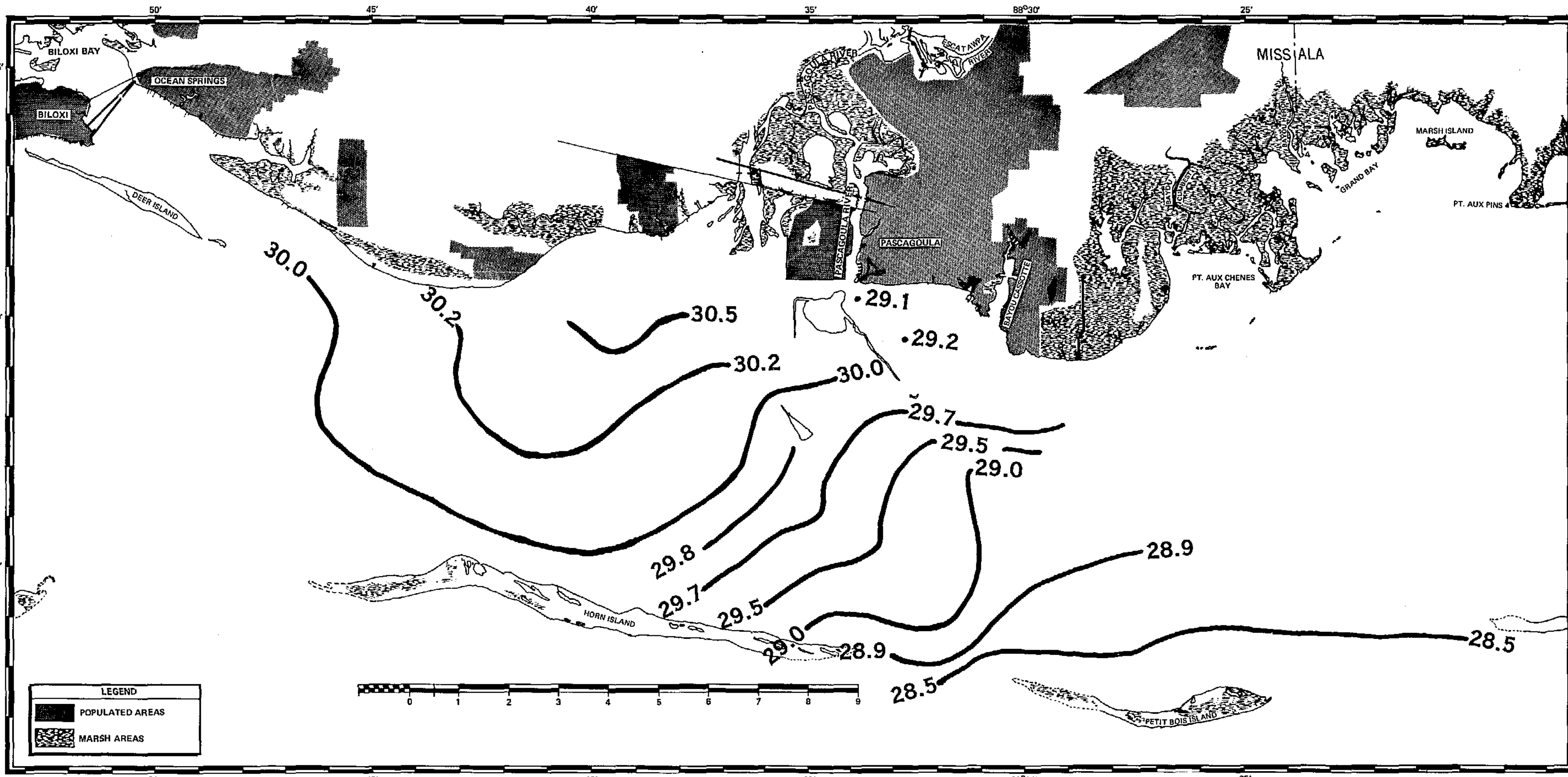


FIGURE 79. SURFACE TEMPERATURE, MISSISSIPPI SOUND 14 JUNE 1973.

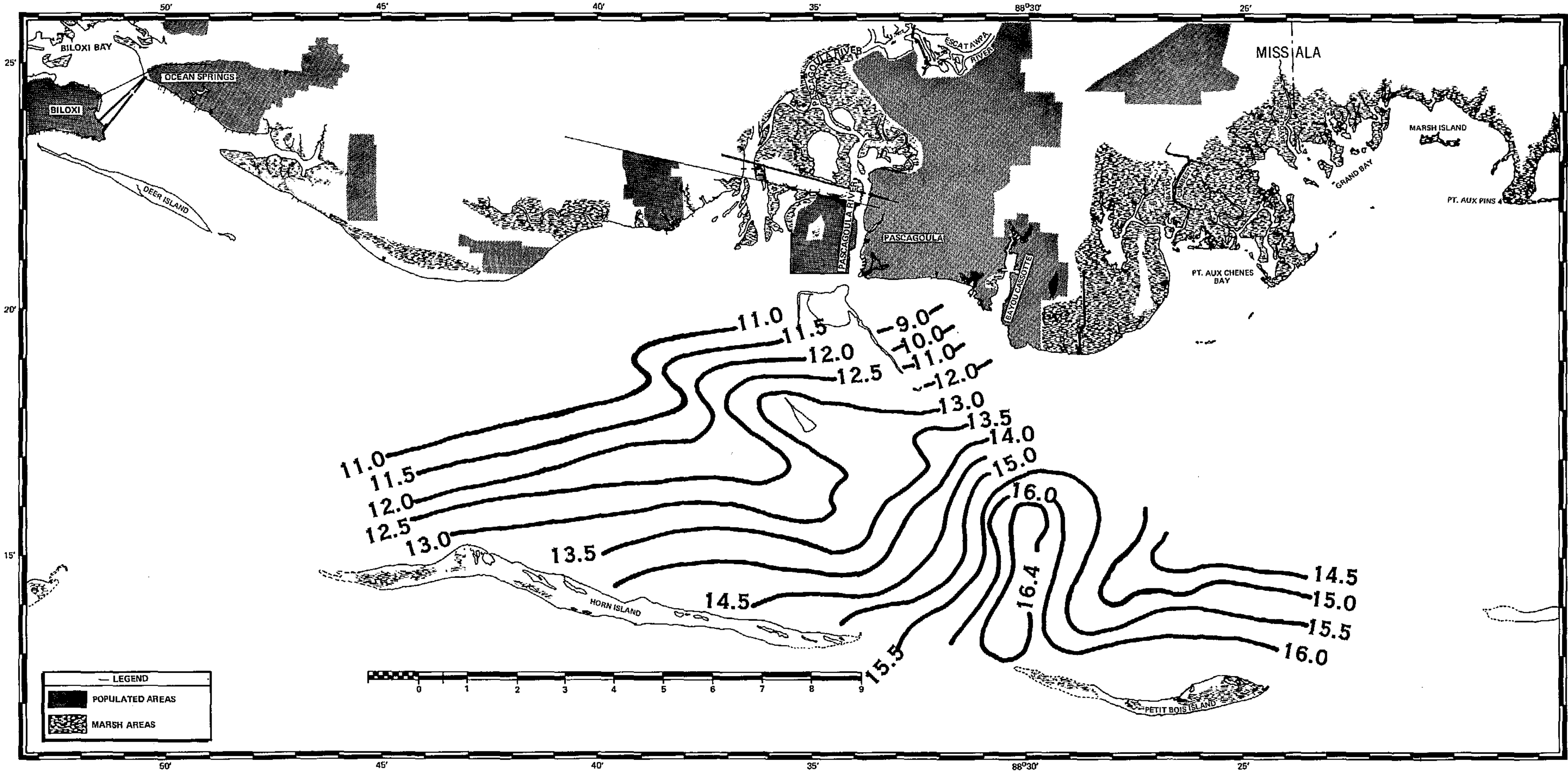


FIGURE 80. SURFACE SALINITY, MISSISSIPPI SOUND, 14 JUNE 1973.

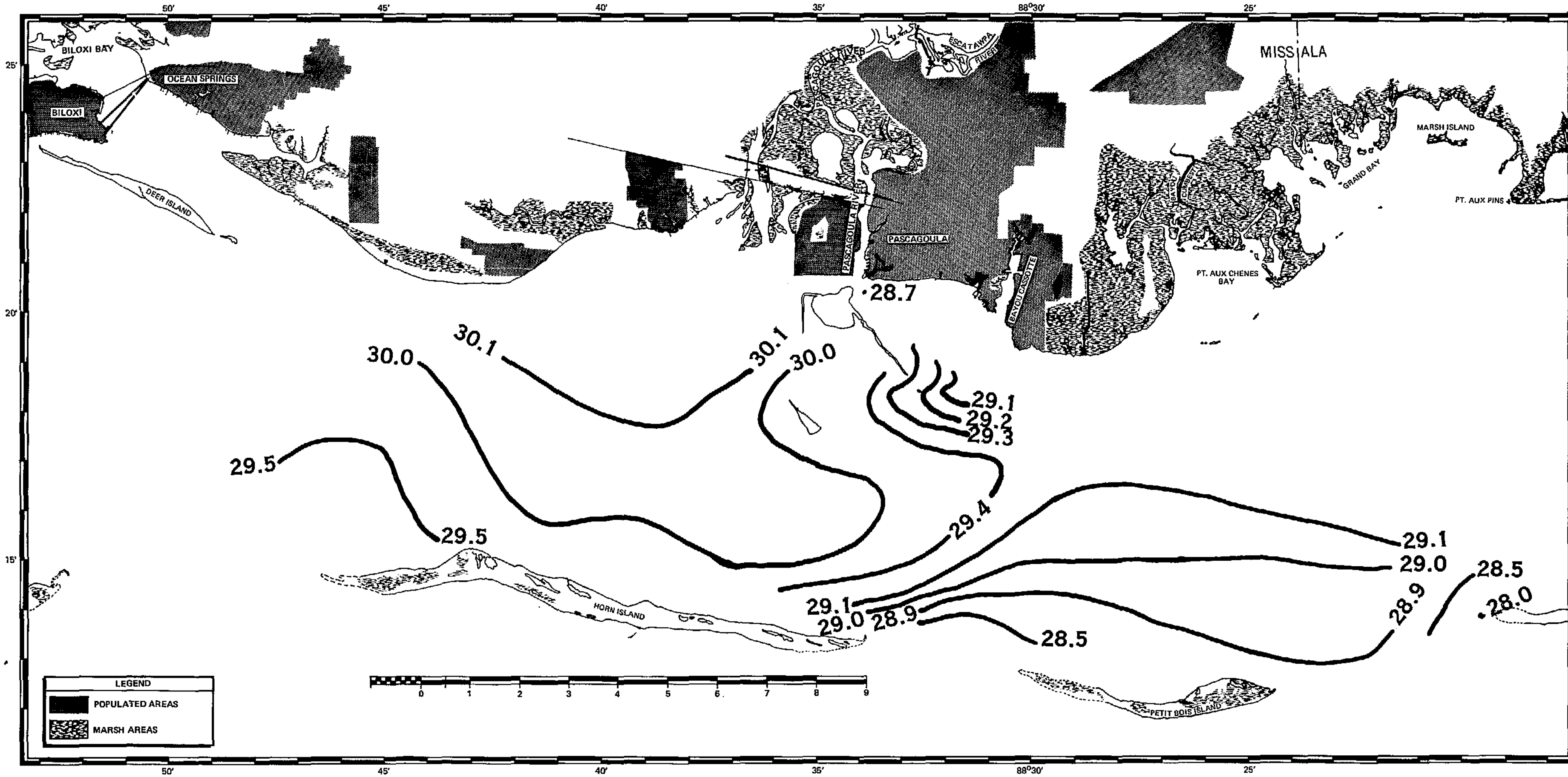


FIGURE 81. SURFACE TEMPERATURE, MISSISSIPPI SOUND, 26 JUNE 1973.

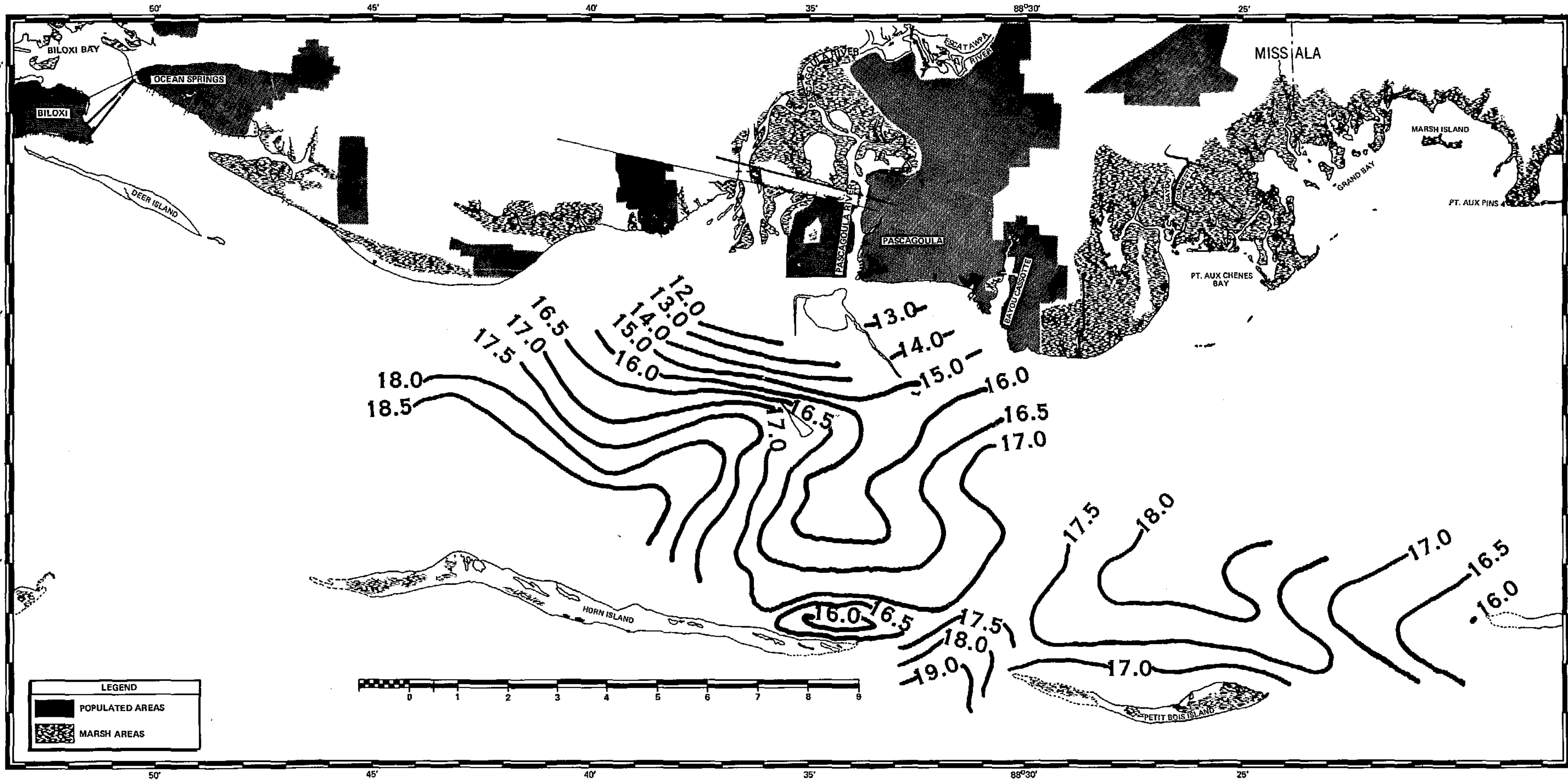


FIGURE 82. SURFACE SALINITY, MISSISSIPPI SOUND, 26 JUNE 1973.

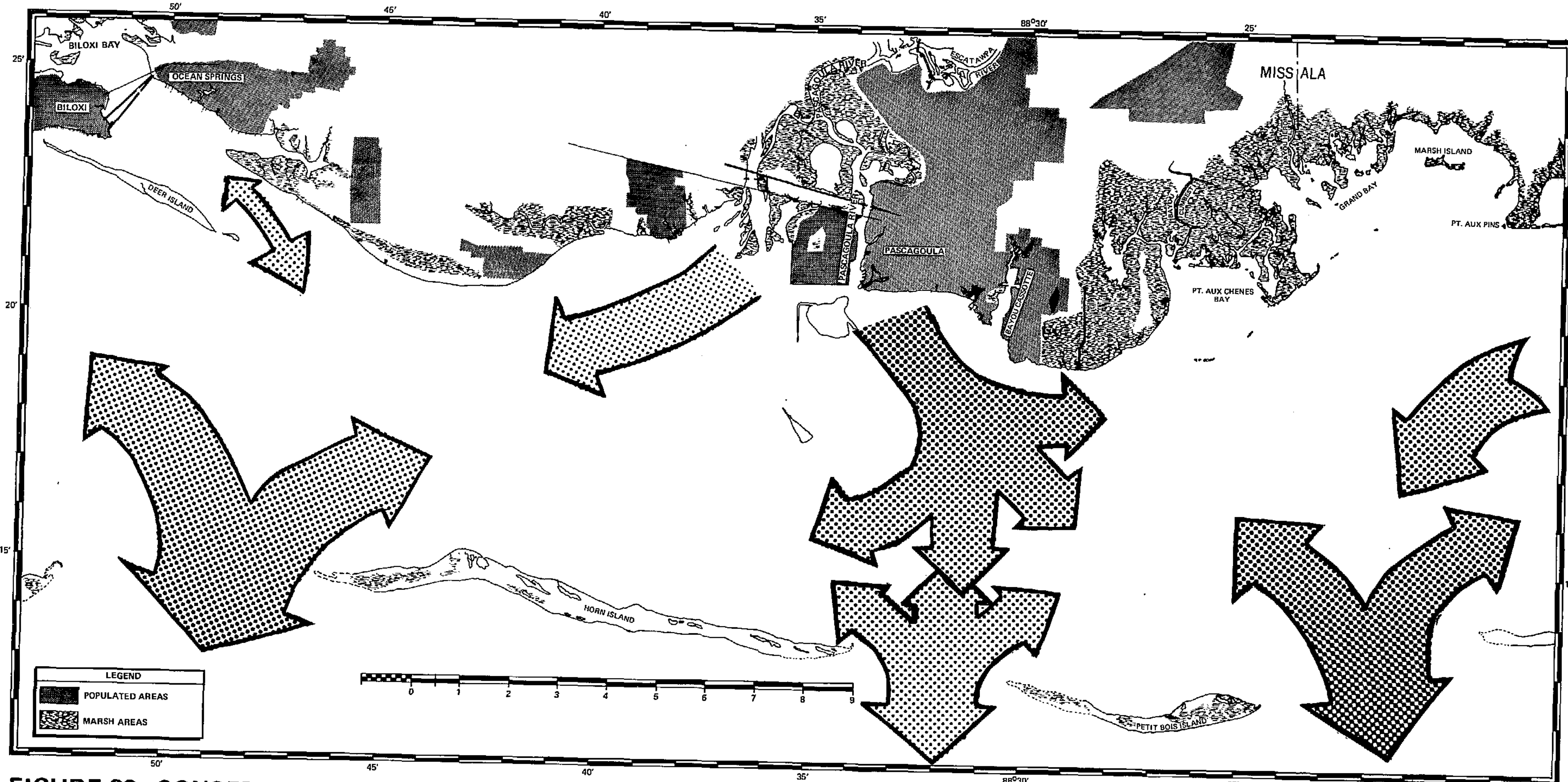
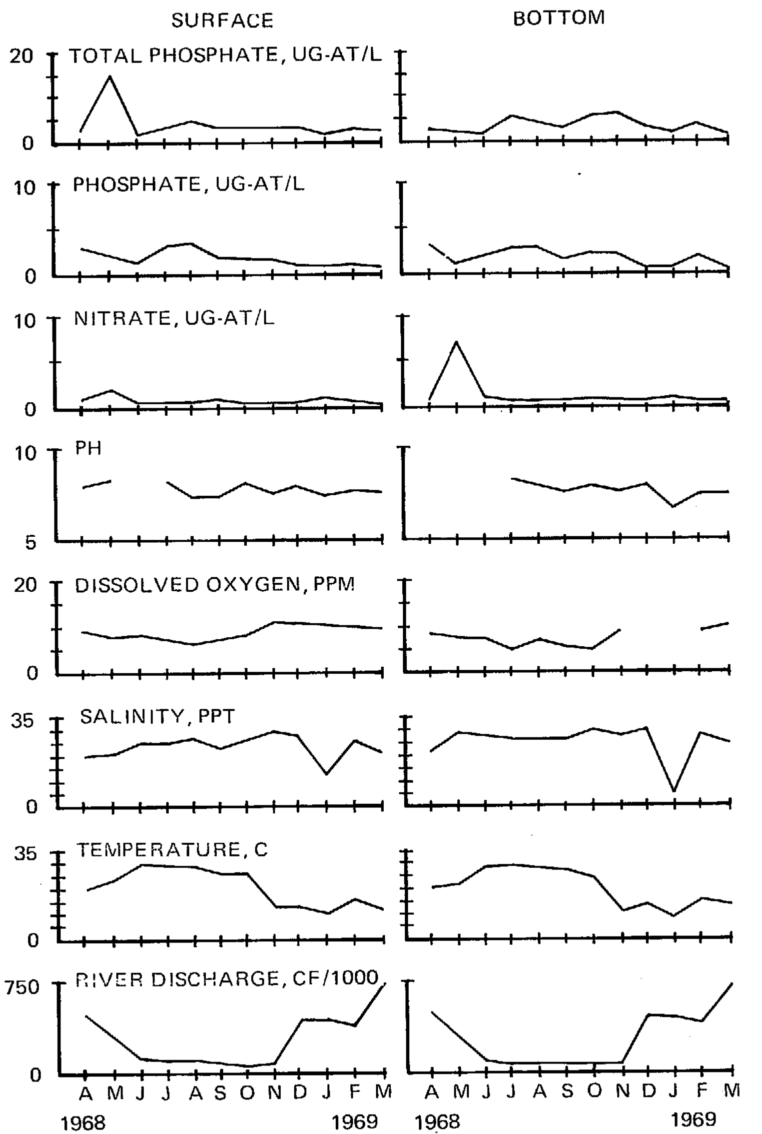
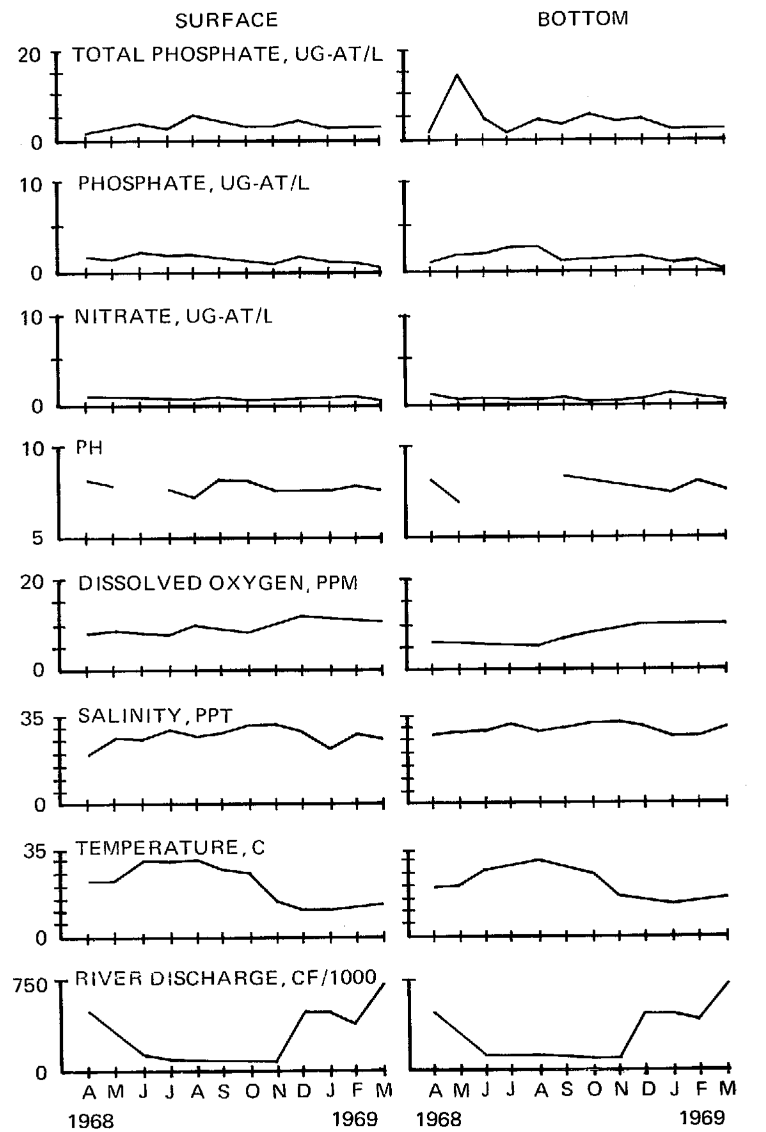


FIGURE 83. CONCEPTUAL REPRESENTATION OF EAST MISSISSIPPI SOUND CURRENTS.



HYDROLOGICAL PARAMETERS IN
EAST MISSISSIPPI SOUND

FIGURE 84. PHYSICAL - CHEMICAL PARAMETERS OF EAST MISSISSIPPI SOUND FROM MAINLAND TO MID-SOUND.



HYDROLOGICAL PARAMETERS IN
EAST MISSISSIPPI SOUND

FIGURE 85. PHYSICAL - CHEMICAL PARAMETERS OF EAST MISSISSIPPI SOUND FROM MID-SOUND TO ISLANDS.

PHOTO 5. COMPACT GRASS ELLIPSOIDS CREATED BY HURRICANE BETSY, 1965. Charles K. Eleuterius

Climatology

General Controlling Meteorological Conditions

The subtropical anticyclonic Bermuda High exerts the greatest influence on the climate of the Gulf of Mexico and contiguous land areas. The Bermuda High intensifies during the spring extending its boundaries into the Gulf of Mexico region. This extension into the Gulf results in a shift in the source direction of the winds to the southeast and south. The wind speeds are much reduced from those of the winter and fall. In early fall the Bermuda High diminishes in strength and its boundary of influence retreats from the Gulf region. Simultaneously with this southeast emigration of the Bermuda High is a southward advance of the continental pressure systems over the Gulf. Accompanying this move, the predominant winds become northerlies. Graphical and tabular presentations of wind data appear in Figures 25-37.

During winter, westerly systems influence the study area as cold fronts from the northwest move southward over the Gulf of Mexico. When these cold fronts, modified by the relatively warm Gulf waters, oppose strong maritime tropical air moving in the opposite direction, the front becomes almost stationary. Under these conditions the northern Gulf area becomes subject to cyclogenesis resulting in low cloud ceilings and precipitation.

Because of the large heat-storage capacity of water and the size of the Gulf of Mexico, the Gulf greatly influences the predominant year-around maritime tropical climate of the study area.

Air Temperature

Southerly winds from over Gulf waters during summer have an ameliorating effect on the heat of the immediate coastal area. Based on 30 years of records, there is an average of only 52 days per year when the temperature exceeds 90F. This figure is approximately half as often as areas only 80 miles inland. Although temperatures infrequently have exceeded 100F, the average summer high temperature is 88.9F. The summer southerly winds from over the relatively cooler Gulf waters effectively reduce the air temperature for a summer average of 81.5F. The winters are generally mild with an average of only 11 days per year when temperatures fall below 32F. There are no records of sub-zero temperatures ever having occurred. The average temperature for the winter months is 54.5F with an average minimum temperature of 46.3F. The dates of the first and last freezes, averaged from recorded data, are 12 December and 21 February, respectively. The average temperature for the year is 68.2F.

Precipitation

There is an average of 58.58 inches of rain per year on the Mississippi Gulf Coast. The wettest month is July with 7.33 inches of rain due primarily to the frequency of thundershowers. September and March are next in amounts of precipitation with 6.50 and 6.10 inches, respectively. The driest months are October and

November when the dry continental air masses push southward over the area causing clear skies and cool nights. Due to the close proximity of the cooler water surface of the Gulf, summer showers are less frequent and lighter than those 50-100 miles inland.

Measurable snow has fallen on the Mississippi coast only 8 times in the past 78 years (February 1899; January 1935; March 1954; January 1955; February 1958; January 1964; January 1973; February 1973). Being of such rare occurrence, the appearance of snow on the Mississippi coast is considered by local residents to be an impressive phenomenon. Due to the relatively warm winter temperatures, the snow melts rapidly leaving only traces by late afternoon.

Humidity and Fog

Prevailing southerly winds during summer carry moist air over the northern Gulf coast. The combination of high humidity and high temperature sometimes causes discomfort to those not acclimated to such conditions. Cold air masses moving out over the Gulf in winter lower the sea surface temperature. This, therefore, provides the mechanism for the formation of advection-radiation fogs along the coast from November to March. Dense sea fog forms offshore over the relatively cold water surface.

Thunderstorms, Thundershowers, Extratropical Cyclones, Waterspouts

There is an average of 75 days when thunderstorms occur along the Mississippi coast. The moist air provided by the southerly winds results in more frequent showers during summer than in other seasons. Thundershower activity increases during the day with 30 percent occurring between 6 a.m. and noon and 60 percent between noon and 6 p.m. The frequency of thundershowers is highest in July. The Mississippi coast is far south of the usual path of winter cyclones, but on rare occasions one will traverse the area. While statistics on waterspouts do not exist for the Mississippi coast, waterspouts are observed but seldom come ashore.

Tropical Storms and Hurricanes

Tropical cyclones which derive their energy primarily from the latent heat of condensation of water vapor are generally from 60 to 600 miles in diameter at maturity and only rarely exceed 1,000 miles in diameter. The speed of the maximum winds is used as the criterion for classifying tropical cyclones. Circulations with maximum sustained winds up to 38 mph are tropical depressions. Tropical cyclones with sustained winds from 39 to 73 mph are categorized as tropical storms. When the maximum sustained winds exceed 73 mph, the tropical cyclones are called hurricanes. The term "hurricane" is used in the North Atlantic region, Caribbean Sea, Gulf of Mexico, eastern North Pacific, and the western South Pacific. In the western North Pacific, cyclones of comparable intensity are referred to as typhoons.

In warm tropical ocean regions where evaporation rates are very high, large quantities of water vapor are transmitted to and stored in the atmosphere. When the vapor condenses and precipitates, latent heat is converted to sensible heat and kinetic energy in the form of winds. Warm ocean areas thus serve as enormous reservoirs of energy used in the development and maintenance of tropical cyclones. The migration of the tropical cyclones into regions of cooler water or over land removes this source of energy.

The awesome destructive power of a fully developed hurricane is in the form of extremely strong winds, torrential rainfall, and high tides and waves. A tremendous amount of property damage, totaling in the billions of dollars, has been attributed to hurricanes hitting the continental United States since 1900. More than 12,000 people have lost their lives in hurricanes in the United States during the same period. In 1900, 6,000 people were killed in Galveston, Texas, during a single storm surge.

Since 1875 (Figure 86) only 17 tropical storms or hurricanes have crossed the Mississippi coastline. Of these 17, only 8 were of hurricane intensity. However, Mississippi has been affected by high winds, high tides or heavy rains from 70 tropical storms or hurricanes during this period.

On 17 August 1969, the most powerful hurricane that has ever entered the North American Continent struck the Mississippi coast with winds of 200 mph and an accompanying surge that drove the water elevation to 22.6 feet above mean sea level. It continued inland through Mississippi, crossed Tennessee, Kentucky, and Virginia, and finally reentered the Atlantic. In the three Mississippi coastal counties it left in its wake: 3,861 destroyed homes; 39,744 homes damaged from near destruction to light; 322 businesses destroyed; and 1,668 businesses damaged. One hundred thirty-four people were killed and others were never accounted for.

Because of the counterclockwise winds of the hurricanes, the northeast quadrant of the cyclone is the most damaging to the northern Gulf coast. The winds of this quadrant pile water up against the coast and also drive large waves in a north or northwest direction. Due to the severity of the northeast quadrant, the direction of approach greatly determines the effect upon the Mississippi coast. Hurricanes that move northeastward from the general direction of the Mississippi River Delta and strike the coastline east of Mississippi are the least damaging as the winds encountered over Mississippi would be from the north or northeast and would thus drive the water away from the coast. Hurricanes that make landfall in southeast Louisiana usually have considerable effect on the Mississippi coast because of the effect of the northeast quadrant. Hurricanes that might move westward offshore of Mississippi would also result in high tides, waves, and winds along the Mississippi coast.

The reversed Z configuration of the coastline formed by the Mississippi River Delta and the Mississippi coast makes the Mississippi coast especially vulnerable when northeast quadrant hurricane winds prevail over the area. Enormous quantities of water are pushed into the Sound by these winds and move westward along shore through the Sound. The barrier formed by the Mississippi River Delta formation to the west, preventing any further westward transport, helps build even higher water levels inside the Sound.

While the hurricane season in Mississippi is from June through November, the preponderance of hurricanes occurs in August and September with September accounting for one-half of all occurrences. Hurricane statistics derived for 50-mile segments of the coastline show the probability of a hurricane occurring in any one year on the Mississippi coast (.13) is considerably less than 100-mile segments east and west of Mississippi (.21).

Since hurricanes are such awesome powers and do invoke considerable damage, the problem of hurricane occurrence in the proposed site area will be addressed further. The object is to estimate the probability of a hurricane making landfall or passing close enough to the proposed Superport site to cause possible damage to the area. With the definition of "significant" including winds higher than 30 mph (statute miles), all tropical cyclones are considered. Tropical cyclones include hurricanes, tropical storms, and tropical depressions (storms with winds up to 38 mph). One should note the inclusion of tropical depressions in interpreting the tabulated probabilities since several of the tropical storms in the defined region were probably too weak to have a significant effect on the area in question.

In developing probability distributions only data concerning North Atlantic tropical cyclones from 1901 to 1963 were considered. Data prior to 1900 is not of a quality to be usable and there is no compilation of figures beyond 1963 available. Since 1900, 500 tropical cyclones were recorded, and 114 of these moved inland or passed close enough offshore to affect significantly various sections of the coasts of Mississippi, Louisiana, and Alabama. Since published data pertained to the Mississippi, Louisiana, and Alabama coasts as a general area, probability distributions were developed in terms of this three-state area. This should not greatly bias our probabilities as most storm centers affecting Louisiana or Alabama coastlines usually produce winds and tides of sufficient strength to affect the Mississippi coast. It is granted that storms moving inland in western Louisiana might have little effect on the area of interest, and the probability estimates could be a slight over-estimate.

Papers by Cry and Thom established that the frequency of tropical cyclones and hurricanes reaching the United States coast was Poisson distributed, i.e., the probability law is defined by $\frac{e^{-\lambda} \lambda^{X}}{X!}$. Data published by Cry pertaining to the previously mentioned three-state area was tested against the assumption that it was Poisson distributed.

The Chi-Square and Kolmogorov-Smirnov goodness of fit tests were used to test the Poisson assumption. Results of these tests appear in tables VIII and IX.

The Kolmogorov-Smirnov cricital value (significance level .01) is $1.63/\sqrt{63} = .205361$, and since our test statistic is less than .205361, we accept the hypothesis of a Poisson distribution with $\lambda = 1.81$ (mean).

Chi-Square = .92148 and this is less than the critical value of 13.3 (Chi-Square value for significance level .01 with 4 degrees of freedom). Again, the hypothesis of a Poisson distribution with mean = 1.81 is accepted.

The entries of the last two lines in Table IX were combined to form a single class. This was done because the expected number on the last line was too small. Such expected numbers lead to large Chi-Square values which do not reflect a departure of "observed from expected" but only the smallness of the "expected."

The values in the Calculated Probability Function column (P) reflect the probability of X storms per year. There is a probability of .296 that we will have one tropical cyclone within the three-state area. This storm could move inland or pass close enough to significantly affect the area. We could expect about three significant storms each decade.

It is noted that both goodness of fit tests support the hypothesis of a Poisson distribution with mean = 1.81. The Kolmogorov-Smirnov test is a more powerful test than the Chi-Square test and is preferable. Also, the calculated probabilities in table IX are in close agreement with those published by Cry.

Whereas, the above analysis is for all tropical storms which either moved inland or remained offshore and moved inland in another area, table X and the resulting conclusions pertain to a storm moving inland in the three-state area being considered.

Kolmogorov-Smirnov Statistic = .049 which is less than the critical value of .205361, and we accept the hypothesis of a Poisson distribution with mean = 1.32.

The probability of one tropical cyclone moving inland in the three-state area would be .35283. Again, we should expect at least three tropical cyclones per decade in this three-state area.

According to Cry, the regions of maximum tropical cyclone activity have been Florida, Texas, the middle Gulf Coast, and the Carolinas. The probabilities generated tend to reflect such an activity.

TABLE VIII

POISSON DISTRIBUTION OF TROPICAL CYCLONES AFFECTING THE MISSISSIPPI, LOUISIANA, ALABAMA COAST, 1901-1963

Kolmogorov-Smirnov Test

No. Storms Per Year	Observed Frequency	Observed Cumulative Frequency	Relative Cumulative Frequency	Expected Cumulative Frequency	Kolmogorov-Smirnov Statistic
0	10	10	.15873	.16365	.00492
1	20	30	.47619	.45987	.01632
2	14	44	.69841	.72794	.02953
3	12	56	.88889	.88968	.00079
4	5	61	.96825	.96286	.00539
5	2	63	1.00000	.98936	.01064

$\overline{X} = 1.81$, $S^2 = 1.74$

Kolmogorov-Smirnov Statistic = .02953

TABLE IX

POISSON DISTRIBUTION OF TROPICAL CYCLONES AFFECTING

THE MISSISSIPPI, LOUISIANA, ALABAMA COAST, 1901-1963

Chi-Square Test

No. Storms Per Year (X)	Observed Frequency	Expected Frequency	$(\text{Obs-ex})^2/\text{ex}$	Calculated Probability Function (P)	Probability Annual Frequency $\geq X$
0	10	10.31022	.00933	.163654	1.00000
1	20	18.66148	.09601	.296214	.83635
2	14	16.88857	.49405	.268072	.54013
3	12	10.18940	.32173	.161736	.27206
4	5	6.95033	.00035	.110323	.11032
5	2				

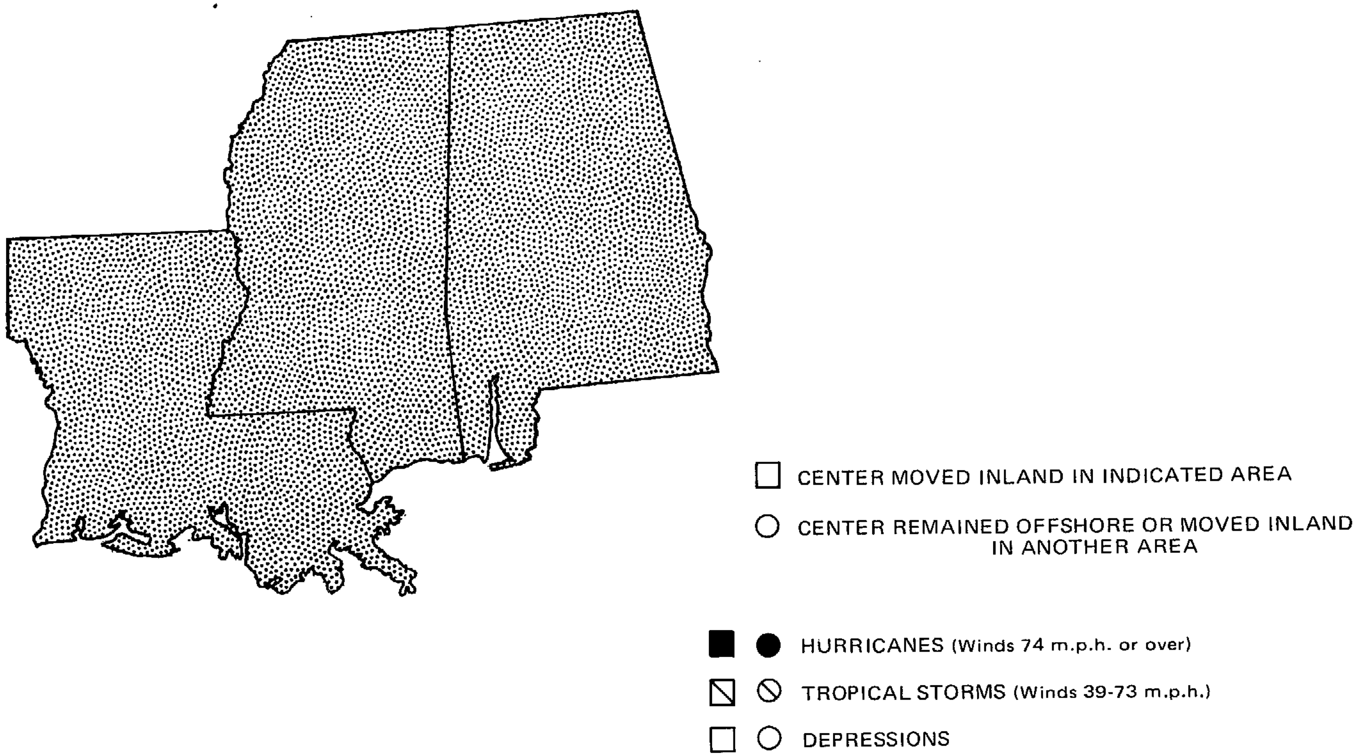
TABLE X

POISSON DISTRIBUTION OF TROPICAL CYCLONES REACHING

THE MISSISSIPPI, LOUISIANA, ALABAMA COAST, 1901-1963

No. Storms Per Year (X)	Calculated Probability (P)	Observed Frequency	Calculated Frequency	Probability Annual Frequency (1-P) $\geq$X
0	.26781	17	16.872	1.00000
1	.35283	19	22.228	.73219
2	.23242	19	14.642	.38936
3	.10207	7	6.430	.14694
4	.03362	0	2.118	.04487
5	.00886	1	.558	.01125

$\overline{X} = 1.32$, $S^2 = 1.19$



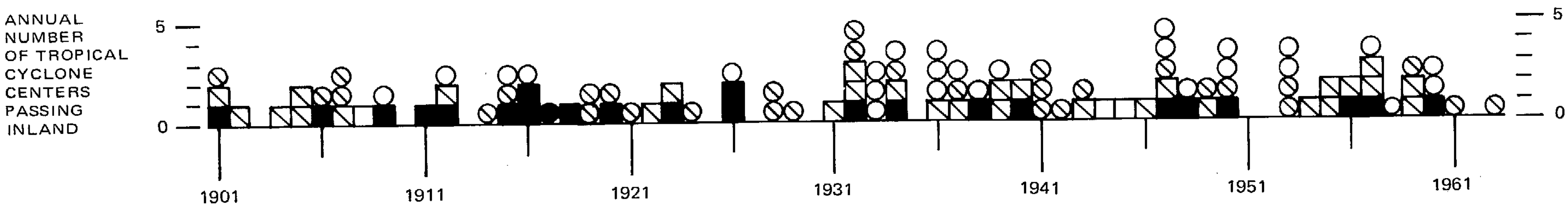


FIGURE 86. HURRICANE, TROPICAL STORM AND DEPRESSION STATISTICS 1901 - 1961.

PHOTO 6. VIEW OF TYPICAL MISSISSIPPI SALT MARSH.

BIOTA

Marshes

It is highly probable that marshes are the least understood, most underrated, and most abused pieces of land in the world. Historically, they have been the victims of avarice and ignorance, and due to the erroneous belief that marshes serve no useful purpose and being equated with deserts, they have been despoiled and destroyed. In actuality, very little land usage is as productive as are the salt marshes. Not only do marshes produce vast quantities of nutriently rich vegetation but they also provide many beneficial services.

Marshes are the vegetated, soft-land areas that border the estuaries and banks of the lower rivers. These areas, interfaces between the water and upland environment, are unique habitats that provide food and protection to many aquatic and terrestrial animals.

The marsh substrate is the result of sediment deposition by river outflow. As a river widens near the mouth and the river outflow confronts the waters into which it is discharged, the velocity of the outflow is greatly reduced. This reduction in velocity reduces correspondingly the ability of the river to keep the sediment in suspension and it thus settles to the bottom. The continued sedimentation process results in the construction of bars and banks on which marsh plants later appear. After such a lengthy developmental process, a marsh is established.

Dead plant material is attacked by bacteria that decompose the plant material found within the marsh. This decomposed composition of plant material and bacteria is called detritus. Tidal action carries the detritus out of the marsh into open waters where it is consumed by an array of marine organisms including oysters, shrimp, and mullet.

The young of many sport and commercial species enter the estuarine marsh areas where they find an abundant food supply and protection from predators. These young remain in the vicinity of the estuarine marshes until they have reached a certain stage of development at which time they depart. Due to this role served by the marshes of the estuaries, the word "estuary" has become synonymous with "nursery area." Some phase of the life-cycles of the major portion of the species found in the study area is estuarine related.

With their thick root system, marsh grasses are a bulwark against bank and beach erosion. During storm conditions when the marsh is inundated, waves traveling through or over the marsh are greatly reduced or completely dissipated by friction with the grass surfaces. Where present, this frictional barrier decidedly reduces the damage that would otherwise be invoked by waves.

The marsh slows the rapid water run-off from upland areas causing it to deposit its sediment load within the marsh region. In absence of marsh, this sediment would be discharged directly into the receiving waters thus increasing the turbidity of the water.

Increased siltation rates would then result in accelerated filling of navigation channels thus requiring more frequent and costly maintenance dredging.

Marshes assimilate some chemical constituents that, occurring in abnormal levels as a result of domestic and industrial effluent loading, reflect polluted systems. Without marshes to help reduce excessive levels of these chemical components, the assimilative capacity of the estuary would diminish increasing the possibility of its attaining a state of pollution.

The straight-line distance near the coast from East Pearl River, the west state boundary, to the Mississippi-Alabama line is approximately 68 miles. The actual coastline, however, is much longer due to the presence of rivers, bays, bayous, and the irregular shoreline. There are four major drainage systems along the coast: Pearl River, St. Louis Bay, Biloxi Bay, and Pascagoula River. The lowest portion of the rivers and the entire bays are estuarine subsystems of the larger estuary, Mississippi Sound. Each of these subsystems (Figure 87) contain sizable marsh areas.

Mississippi marshes are divided into four regions: Saline, Brackish, Intermediate, and Fresh water. The saline marsh is comprised of two major species; *Juncus roemerianus* and *Spartina alterniflora* which usually form a common boundary. Interspersed with the *J. roemerianus* are some brackish water species *S. cynosuroides*, *S. patens*, and *Scirpus olneyi*. On the "salt flats" that appear throughout the saline-marsh area are found *Salicornia bigelovii*, *Suaeda linearis*, and *Batis maritimus*.

The brackish marsh is differentiated from the saline by the decline in the abundance of J. roemerianus and the decline and eventual disappearance of Spartina alterniflora. There is also an increase over that found in the saline marsh of both brackish and freshwater plant species. Interspersed among the J. roemerianus of the brackish marsh are the following plants: Spartina cynosuroides, Spartina patens, Limonium caroliniana, Boltonai asteroides, Ludwigia sphaerocarpa, Lythrum lineare, Ipomoea purpurea, Scirpus olneyi, Polygonum setaceum, and Sagittaria lancifolia. The absence of S. alterniflora from this area is attributed both to low salinity and lack of suitable substratum.

The lower boundary of the intermediate marsh is defined by the complete disappearance of Juncus roemerianus. This transitional area between the brackish and freshwater marsh areas consists of plants found in both. Plants that are found in this area are: Phragmites communis, Scirpus validus, Cladium jamaicense, Eleocharis cellulosa, Scirpus americana, Sagittaria lancifolia, Pontederia cordata, Crinum americanum, and Iris virginica.

The freshwater marsh consists, generally, of small discontinuous bands bordering the river banks. There is a greater diversity of plant species comprising the freshwater marsh than the other marsh regions. Plant species found in this area are: Eleocharis cellulosa, Eleocharis obtusa, Crinum americanum, Sausarus cernus, Sagittaria lancifolia, Iris virginica, Scirpus americana, Pontederia cordata, Rhynchospors macrostachya, Ptilimnium capillaceum, *Prosperpinaca pectinata*, *Pluchea purpurasens*, *Ploygonum setaceum*, *Scirpus validus*, *Ludwigia sphaerocarpa*, *Boltonia asteroides*, *Zizania aquatica*, *Eleocharis quadrangulata*, *Sium suave*, *Juncus megacephalus*, and *Osmunda regalis*.

There is a distinct lateral zonation between certain marsh species. While there have been a number of theories presented to explain this zonation, present evidence is still insufficient to be conclusive. There is also a difference between Pearl and Pascagoula Rivers with respect to the species composition of the fresh and intermediate marsh regions.

Based on an analysis of fixed line transects, Mississippi's marsh composition is approximately 57.8 percent *J. roemerianus*; 9 percent *Sagittaria lancifolia*; 7 percent *Spartina patens*, 6.5 percent *Spartina alterniflora*; 6 percent *Spartina cynosuroides*. The following species comprise 2.5 percent or less of the marsh vegetation: *Cladium jamaicense*, *Scirpus validus*, *Distichlis spicata*, *Fimbristylis spadicea*, *Osmunda regalis*, *Phragmites communis*, and *Boltonia asteroides*. In 1968 of the 64,805 acres of mainland marsh, 61,398 acres was dominated by *J. roemerianus* and approximately 2,028 acres by *Spartina alterniflora*. *Spartina patens* and *Scirpus olneyi* dominate 460 and 96 acres, respectively. Of the 64,805 mainland marsh acreage, 823 acres is freshwater marsh and 63,982 acres is salt marsh. The barrier islands contain a total of 2,126 acres of salt marsh.

The production of organic matter by Mississippi marshes is estimated in excess of 3 million tons annually.

Based on 1973 figures, since 1930, 8,170 acres of productive Mississippi marsh had been filled for industrial use. Another 85 acres have served as garbage dumps. Land developers, prevented from constructing Venecian-type canals in other states, moved into Mississippi and continued this building practice which destroyed additional marshlands.

Due to the foresightedness of the Mississippi Legislature, a Wetlands Protection Act has been enacted to help prevent the misuse of one of Mississippi's most valuable resources.

Figure 87 shows a portion of the marshes of east Mississippi Sound. Attention should be directed to the extensive marsh area east of Bayou Casotte. This marsh, associated with the abandoned Escatawpa Delta, has remained in an almost pristine condition due mainly to the absence of industrial or domestic land developments. The largest and one of the last relatively undisturbed marsh habitats in the States of Alabama and Mississippi, it provides a rich nursery area for many important marine species.

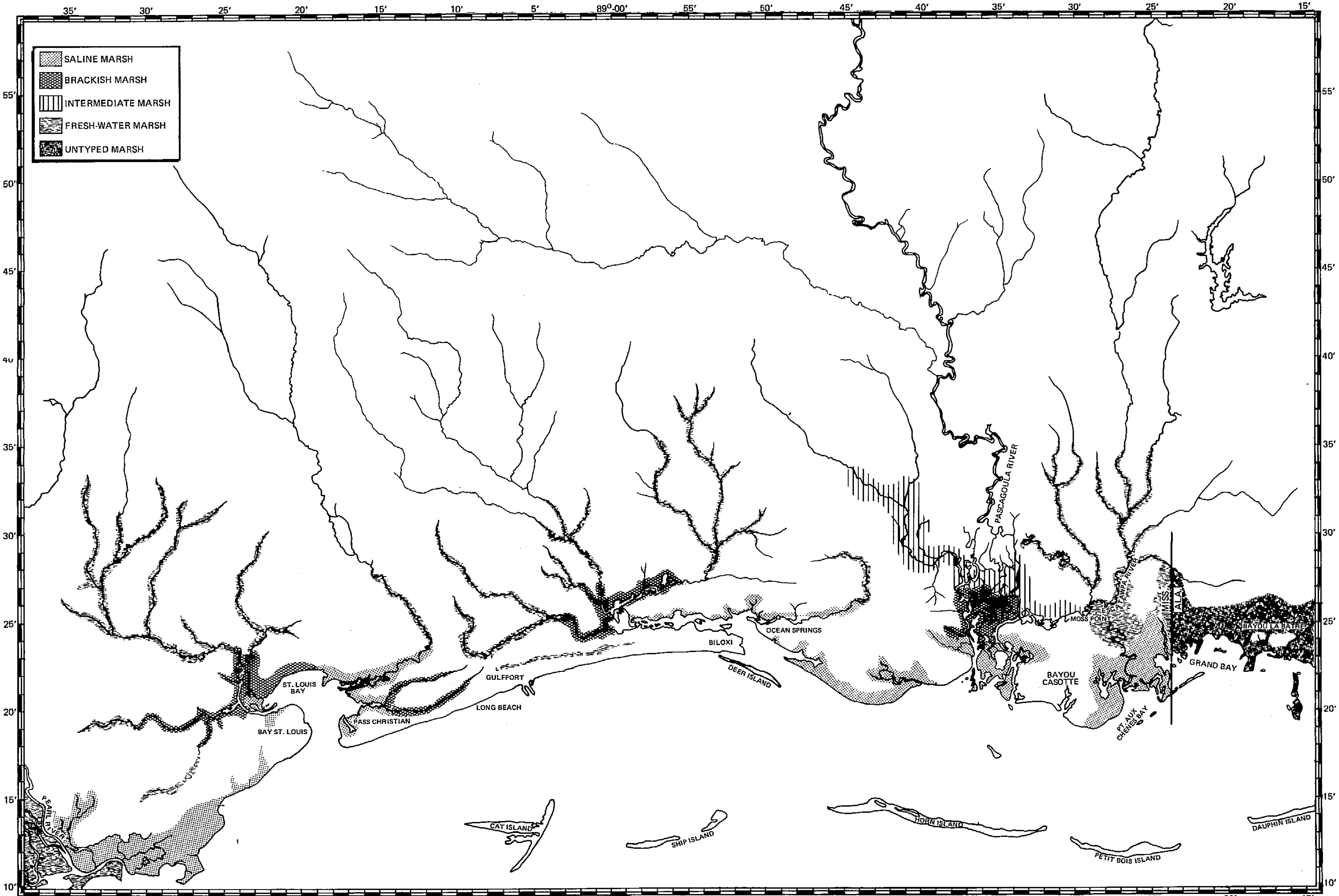


FIGURE 87. MISSISSIPPI-WEST ALABAMA MARSHES.

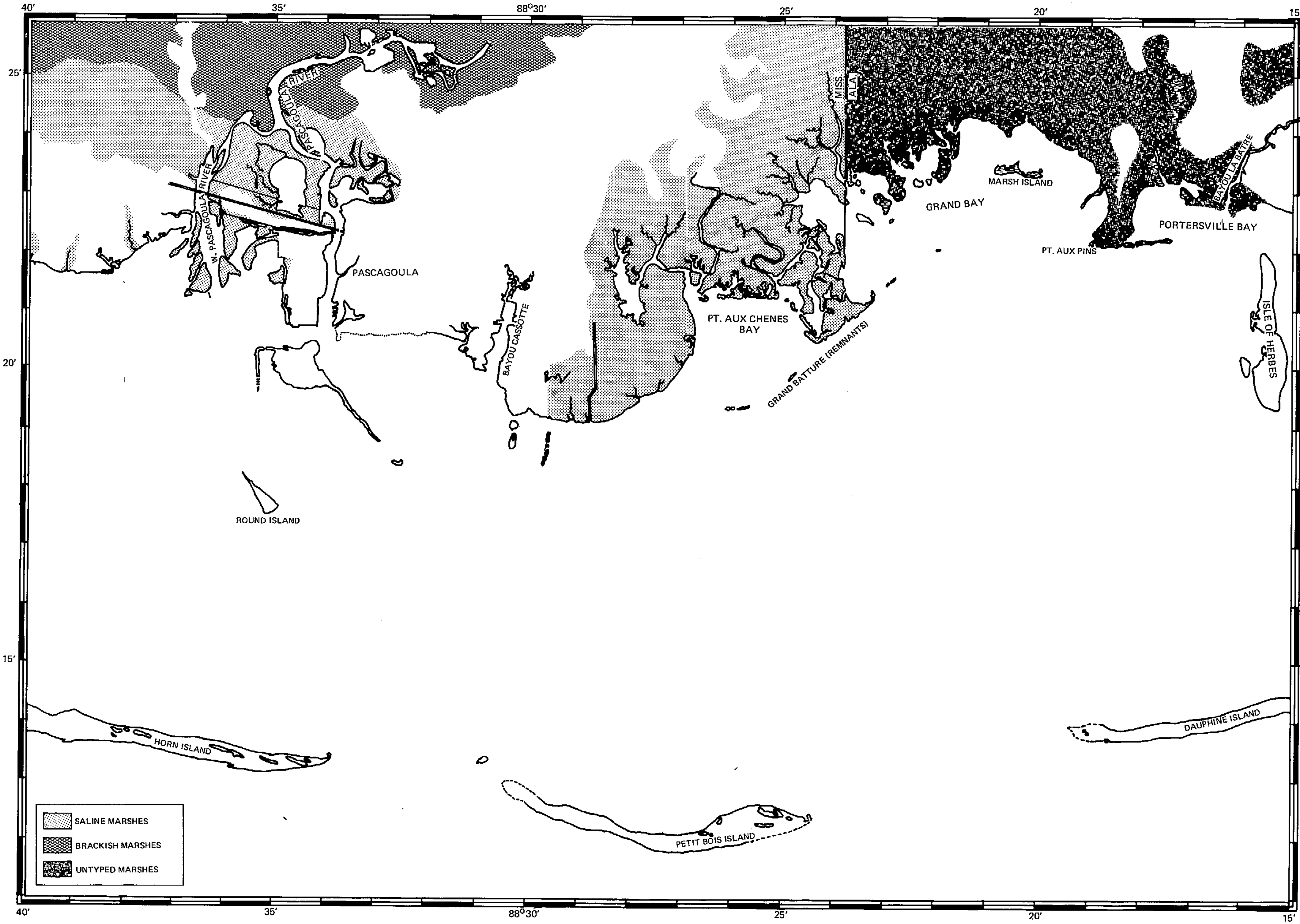


FIGURE 88. MARSHES OF EAST MISSISSIPPI - WEST ALABAMA

Submerged Vegetation

A recent survey revealed that approximately 20,000 acres (31.2 sq. mi.) of submerged vegetation exists within that part of Mississippi Sound in Mississippi. Most of the submerged vegetation is located just north of the barrier islands (Figure 89). Species identified were *Thalassia testudinum*, *Cymodocea manatorum*, *Diplanthera wrightii*, *Halophila engelmanni*, *Ruppia maritima*, and *Vallisneria americana*.

Shoal grass (*Diplantera wrightii*) was found in Point aux Chenes Bay east of Bayou Casotte where a sandy substrate exists. It was also found forming a continuous belt north of Petit Bois Island associated again with a sandy bottom. Shoal grass was discovered in patches on the "Middle Ground," an area approximately midway and north of Horn Island. There the patches appeared separated from other grass species. The species also occurs as patches at Dog Keys, a shallow shoal area between Horn and Ship Islands. A strip of this vegetation is also found north of Ship Island. The lagoons of Cat Island and the area to the west and north, protected from the open Gulf, were heavily vegetated with shoal grass. A small area of this species which is not indicated in the figure is located east of Bayou Caddy in Hancock County. In every instance, shoal grass occurred on sandy bottoms.

Manatee grass (Cymodocea manatorum) was found in waters 4-6 feet deep north of the shoal-grass areas on the mainland side of Horn and Ship Islands.

Over thirty species of benthic algae including red, brown, and green were collected in Mississippi Sound. Widgeon grass (Ruppia maritima) and tape grass were collected in low salinity and freshwater areas in bays and near rivers.

While information on these submerged grass beds is relatively sparse, they are considered to add substantially to the over-all productivity of Mississippi Sound.

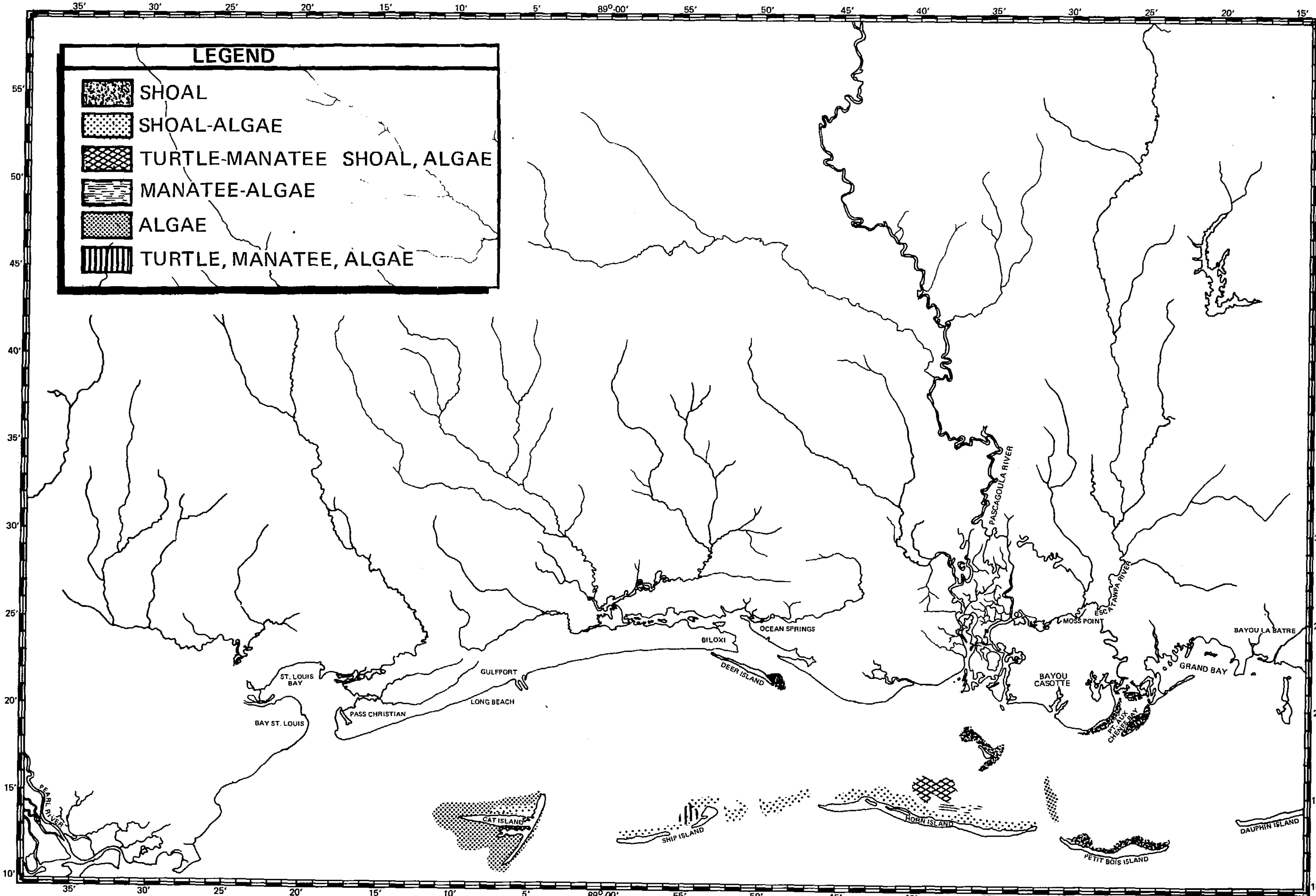


FIGURE 89. SUBMERGED VEGETATION OF MISSISSIPPI SOUND.

Oyster Reefs

Due to the scale of the chart, not all of the Mississippi oyster reefs are shown in Figure 90. Productive, commerically exploitable reefs exist in the following locations: Bangs Lake, Bayou Cumbest, Herron Bayou, West Pascagoula River Delta, Graveline Bayou, Biloxi Bay (four separate reefs), East End Deer Island, Pass Christian, Square Handkerchief, St. Louis Bay, Waveland, and Point St. Joe. Many smaller reefs are scattered throughout the Sound, but the ones mentioned here are the most productive. However, of the estimated 2,030 acres of productive oyster reefs, only 1,035 acres are open to harvesting. Due to pollution, the remainder have been closed to shellfish harvesting by the State of Mississippi Health Department. The pollution criterion utilized in making decisions to close areas for oyster harvesting is an enterococci coli bacteria level above 70 MPN (most probable number) per 100 milliliters of water. Some controversy exists concerning the appropriateness of the method and bacteria level used in declaring an area polluted. In any case, Mississippi is presently realizing approximately only half of the potential productivity of its oyster reefs because of pollution. In the near future, another notable shellfishing area, Graveline Bayou, will be closed - another casualty of pollution. Until a viable plan for waste treatment for the Mississippi Gulf Coast is devised and implemented, it appears that the present trend of pollution will force the State Health authorities to continue closing productive oyster reefs.

The Mississippi Marine Conservation Commission, in order to assure a continuing oyster supply for the Mississippi seafood industry and in the face of the encroaching pollution, has built new reefs in unpolluted waters. This practice of constructing new reefs is no small task. The environment in which a productive oyster reef can be established is restrictive. The immobility of oysters precludes their existence in areas with high siltation rates where they would soon become buried. Oysters are able to live only within a specified range of salinity. If the salinity level is too low due to high rates of river discharge, the oysters die. High salinities within the tolerance range of oysters permits the predacious "oyster drill" (Thais haemastoma) to invade the reefs often annihilating the oyster populace. Bottoms where reefs can become established are also critical. The bottoms cannot be sandy as shifting sands would soon cover the oysters; the bottom cannot be soft mud because the oyster would eventually sink into it and "smother." There are many problems associated with the site selection, development, and maintenance of reefs as productive oystering areas. Improving the water quality and subsequently opening oyster reefs now closed due to pollution would double the present area available for shellfish harvesting.

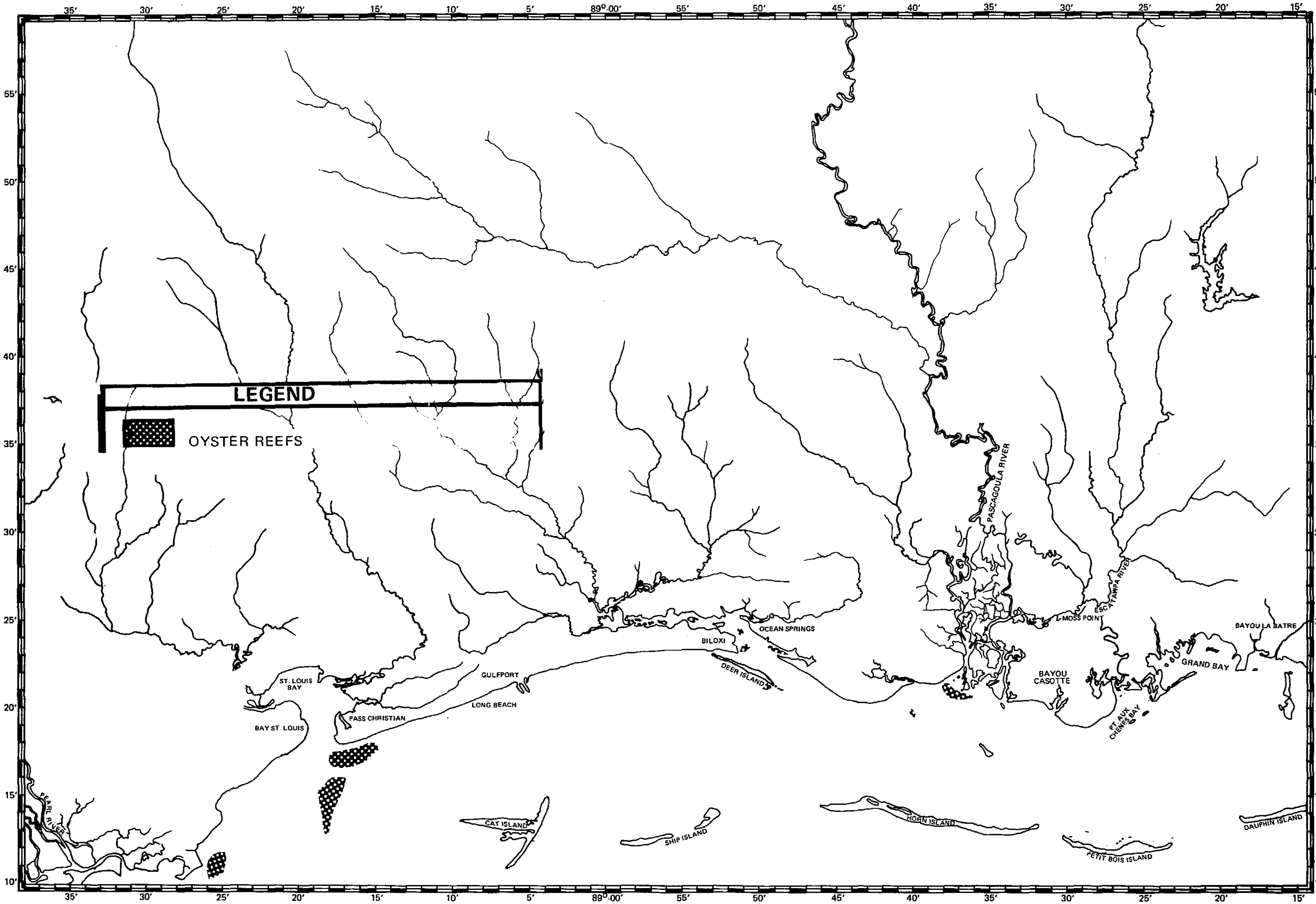


FIGURE 90. MISSISSIPPI OYSTER REEFS.

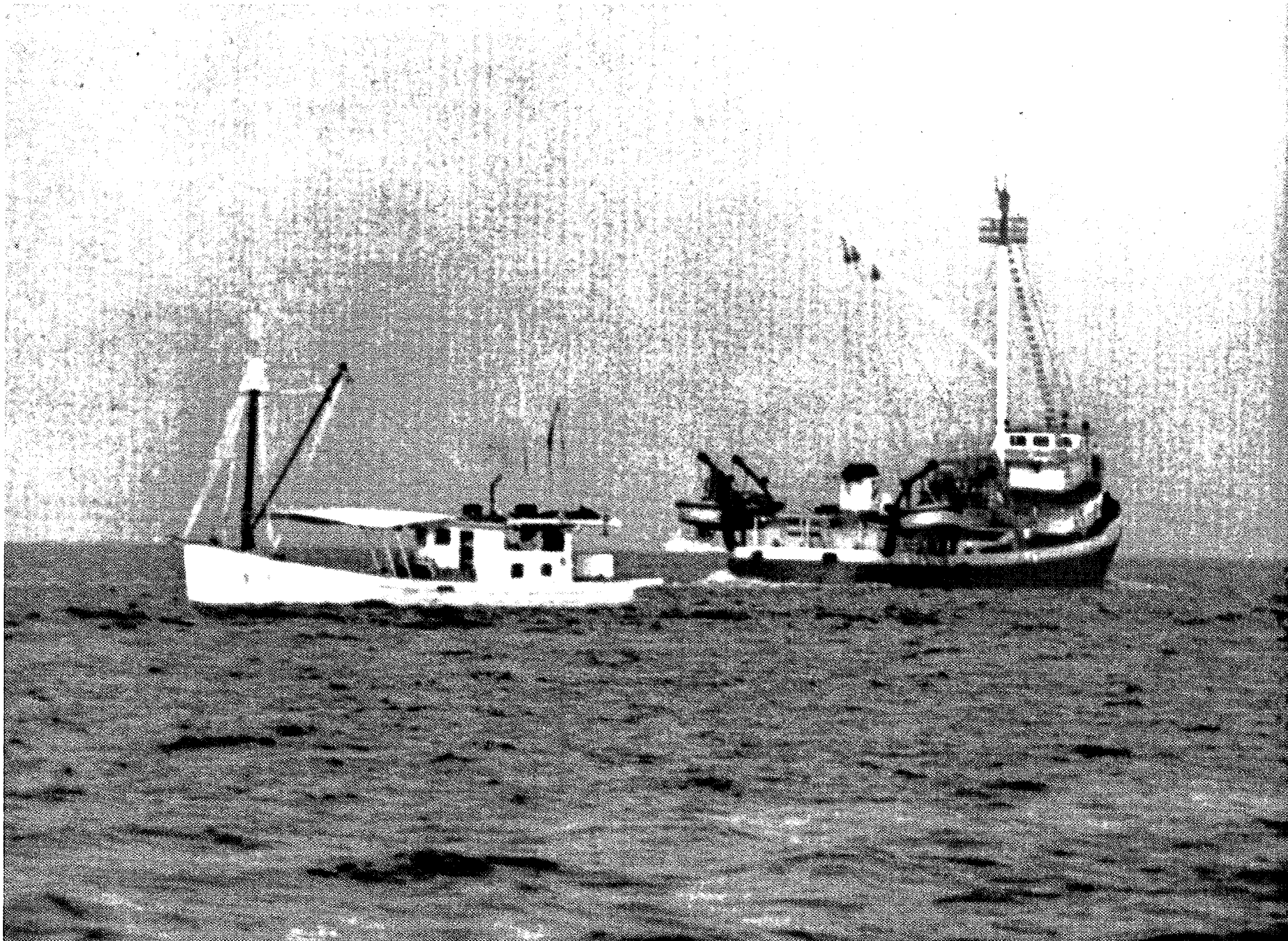


PHOTO 7. MISSISSIPPI SHRIMP BOAT DWARFED BY MENHADEN BOAT.

Charles K. Eleuterius

Commercial and Sport Fisheries

Mississippi's coastal and offshore waters comprise a portion of the "Fertile Fisheries Crescent." Mississippi's long established fishery industry expresses a strength and intensity that probably would not be expected from its relatively short coastline. The state ranked seventh in 1971 in fishery production and presently ranks second among the Gulf states in production volume. The fishery industry employs approximately 4,500 people directly and many others in the ancillary services such as ice and freezing plants, net manufacturers, ship yards, engine distributors, engine repair shops, and fuel suppliers. Mississippi's fishery production, including cat fish farming, for 1973 was evaluated by the National Marine Fisheries Service to have a dockside value of $18,432,000 and a manufactured value of $55,997,000. These figures do not include the contribution realized from support of the ancillary businesses.

As do most other U.S. fishing industries, Mississippi's fishing industry contends with foreign, governmentally-subsidized fisheries. Generally, foreign fishing fleets and factories are better equipped and are not subject to the rigid inspections and laws as in the United States. Figures 91-97 illustrate the production volume and value of some of Mississippi's seafood industries since 1950. The dollar value is indicated at the top of each bar and refers to dockside value in all cases except for the Pet Food Industry (Figure 96).

Mississippi's oyster industry faces a dim future due primarily to encroaching pollution forcing the closing of productive oyster reefs. Since the remaining reefs cannot supply the demand of Mississippi's industry, oysters are now being trucked into the state from Louisiana and Texas. The raw oyster production has increased steadily in the last 20 years (Figure 91). This does not reflect an increase in the resource, but a shift to marketing raw oysters rather than canned ones due to the unfair market advantage of foreign imports. Foreign imports have a cost advantage in that they are not subject to the strict regulations which, in the interest of public health, are imposed on U. S. shellfish industries. The canned-oyster industry has declined in the last decade (Figure 92) due to both the dwindling resource and unfair market competition with foreign products. The sudden decline in 1969 and 1970 reflects the loss of processing capability resulting from the destruction of facilities by Hurricane Camille.

The shrimp fishery has been the mainstay of Mississippi's seafood industry. While the industry faces the uncertainties of an available resource which fluctuates with natural influences, the decline in Mississippi shrimp production (Figure 93) is due primarily to increasing competition from neighboring Alabama. It has been pointed out that Mississippi's shrimp-fishing vessels, generally, are obsolete and are at a disadvantage in competing with the larger horse-power vessels built for the open shelf waters.

The menhaden fishery began in Jackson County, Mississippi, in 1939, and produces three products: oil, solubles, and meal. The meal is used mainly as food for poultry and swine. The products are sold both in the U. S. and foreign markets. Each menhaden vessel costs in excess of $500,000. The catch data and corresponding pre-manufactured value are indicated in Figure 94.

The red snapper industry is a relatively new fishery in Mississippi and its production has increased almost exponentially since its beginning (Figure 95).

The production of pet food from bottom-oriented "industrial fish" has become a sizable industry since its establishment in Mississippi in 1956. The production has been relatively consistent (Figure 96).

Two other important fisheries for which catch figures have not been included are the crab fishery and littoral fishery.

Mississippi's seafood increased rapidly up through 1961; since then there has been a significant decline in volume (Figure 97). Identification of specific problem areas associated with Mississippi's seafood industry is addressed in a recent report (listed in the Literature Referenced section of this report) by fisheries expert Charles Lyles.

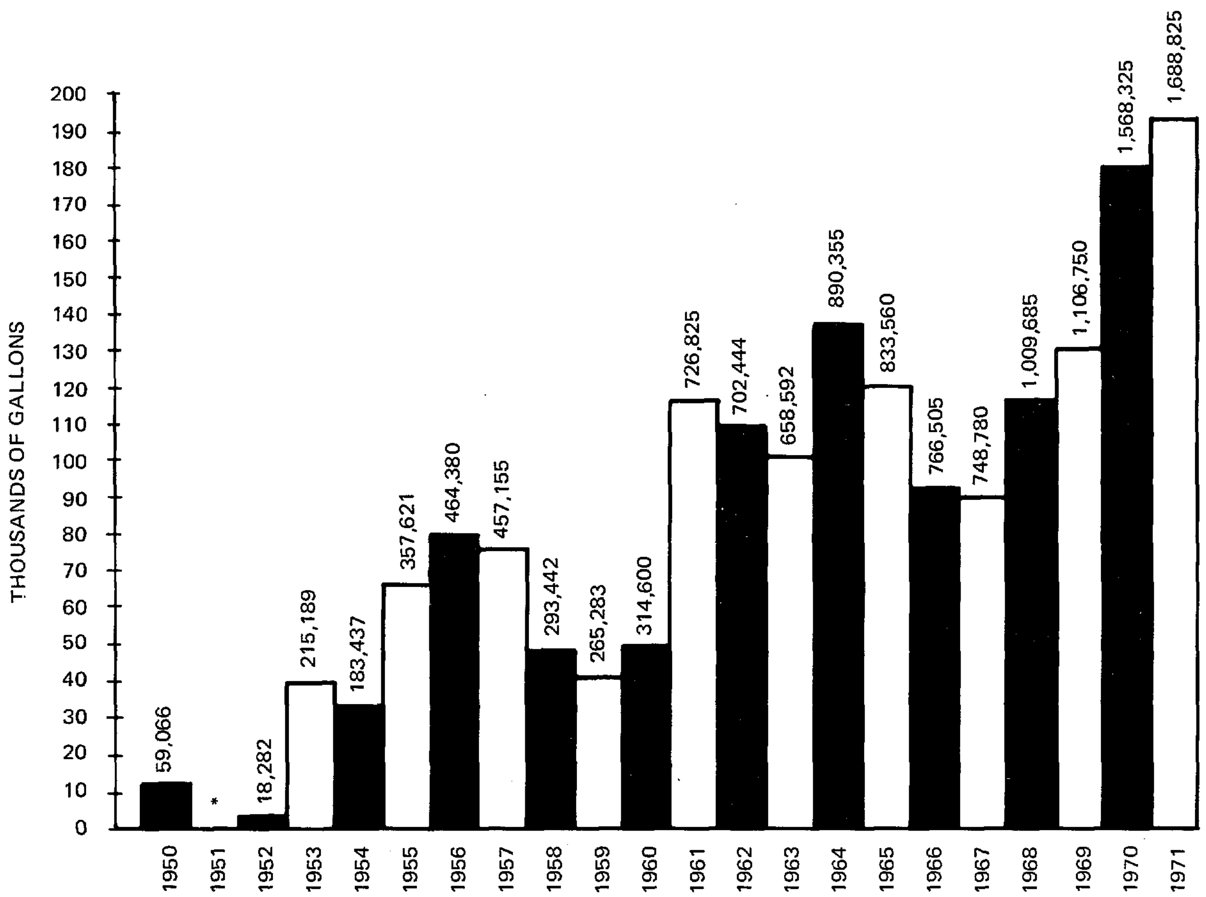
Little information is available concerning Mississippi's sport fishery. While it is felt that the monetary contribution to the economy is considerable, the collection of essential statistics is extremely difficult. The gathering of pertinent information depends strictly on the cooperation of the sport fishermen. Some investigative work in this area is now being conducted, but the financial support is at a level that severely restricts the scope of the study. Aerial surveys, while important, cannot furnish the required catch data, catch composition, and expenses necessary for determining the economic contribution.

The Mississippi coastal area, coastal waters, and shelf waters abound with life. Tables XI-XIV have been prepared to illustrate the fertility and productivity of the study area. While considerable effort went into the preparation of these tables, it is realized that the lists are incomplete because not all the faunae of the area have been identified or reported.

Table XI lists all of the mammals occurring in the study area that have been reported. The reptiles and herptiles found in the area are listed in Table XII. Birds, including migratory birds, that are found in the area comprise a substantial Table XIII. Table XIV incorporates many, but certainly not all, of the organisms that are found in the waters of the study area.

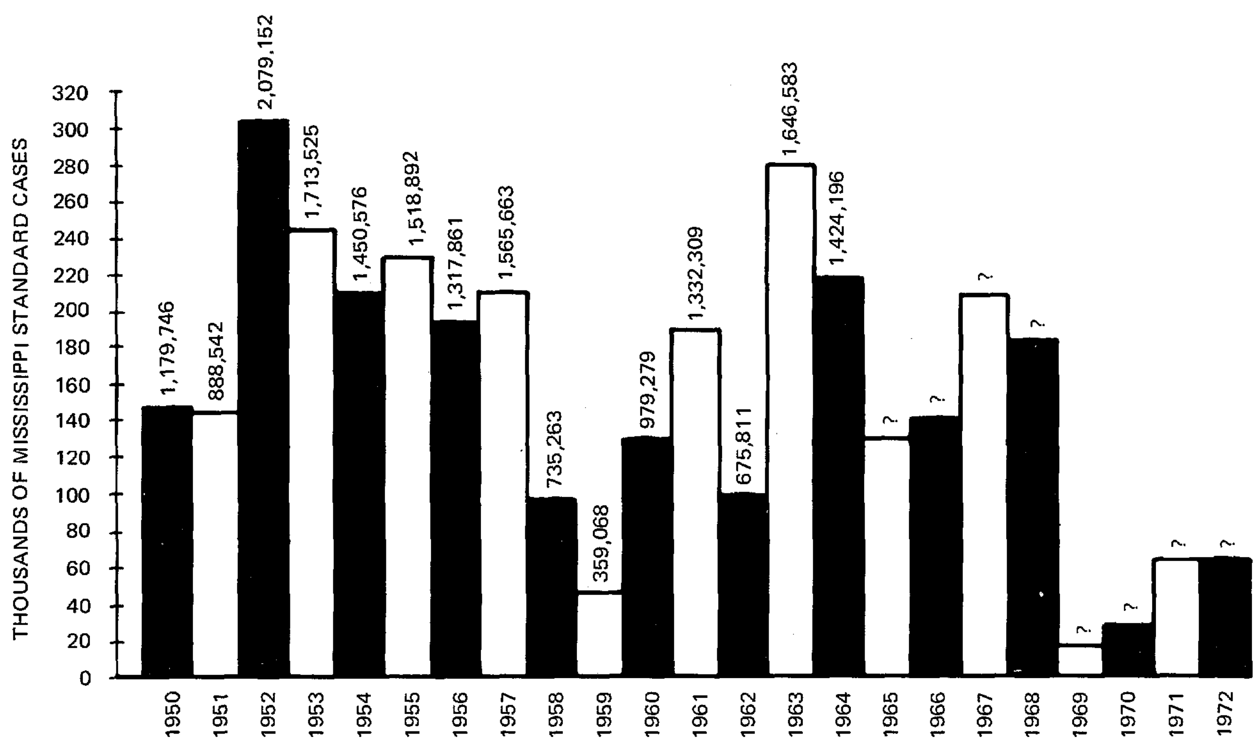
Listed in these tables are a number of endangered species.

Mississippi reaps a bountiful harvest from the sea that it will continue to enjoy with proper management and assistance. This renewable resource is a mainstay of the economy of the coast and the state as a whole, and adequate safeguards must be instituted in locating and operating a Superport in the area.



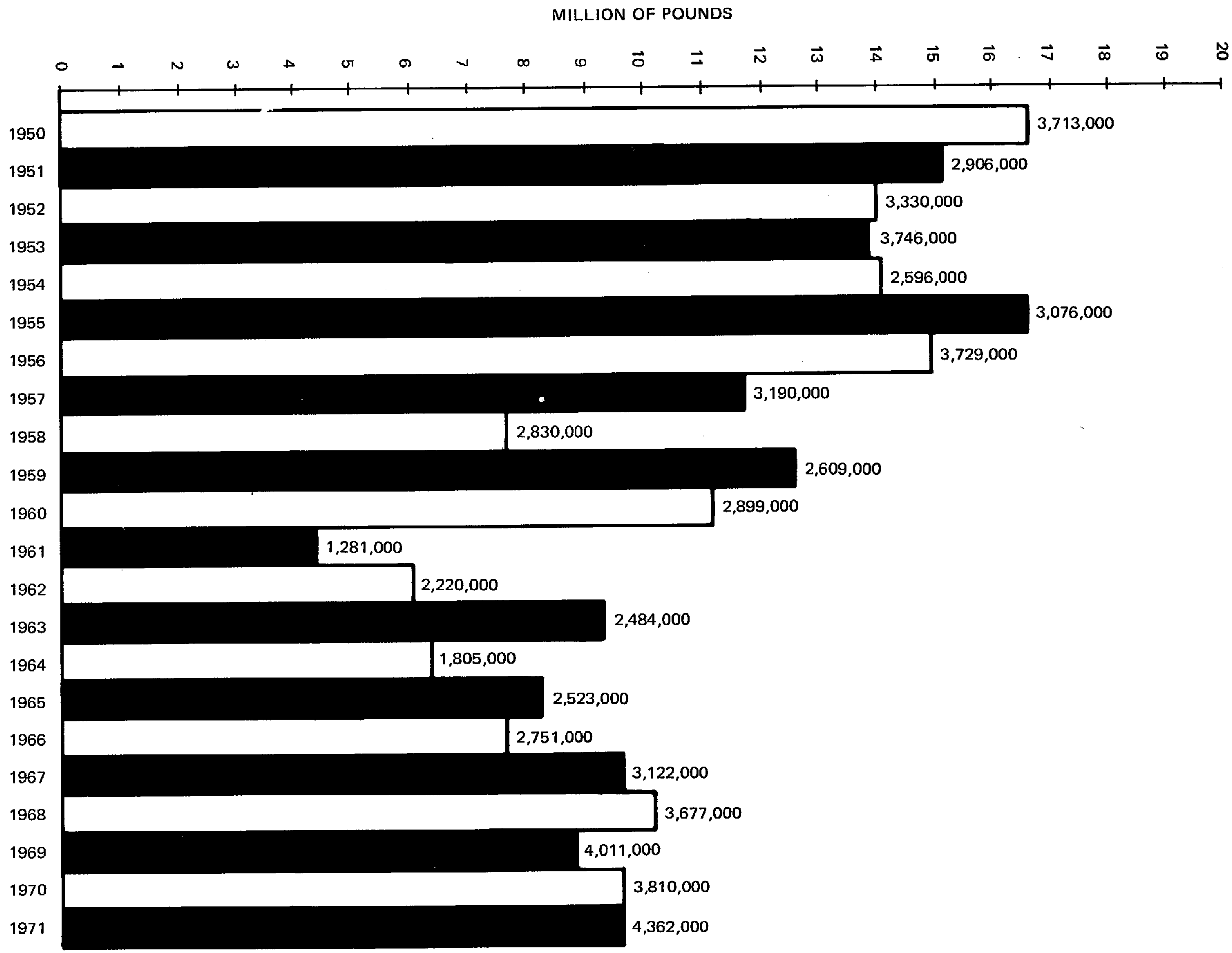
MISSISSIPPI SHUCKED (RAW) OYSTER PRODUCTION 1950-1971
DOLLAR VALUE AS INDICATED

FIGURE 91. MISSISSIPPI SHUCKED OYSTER PRODUCTION 1950 - 1971.



MISSISSIPPI PRODUCTION OF CANNED OYSTERS 1950-1972
DOLLAR VALUE AS INDICATED

FIGURE 92. MISSISSIPPI CANNED OYSTER PRODUCTION 1950 - 1972.



MISSISSIPPI SHRIMP LANDINGS 1950-1971
DOLLAR VALUE AS INDICATED

FIGURE 93. MISSISSIPPI SHRIMP LANDINGS 1950 - 1971.

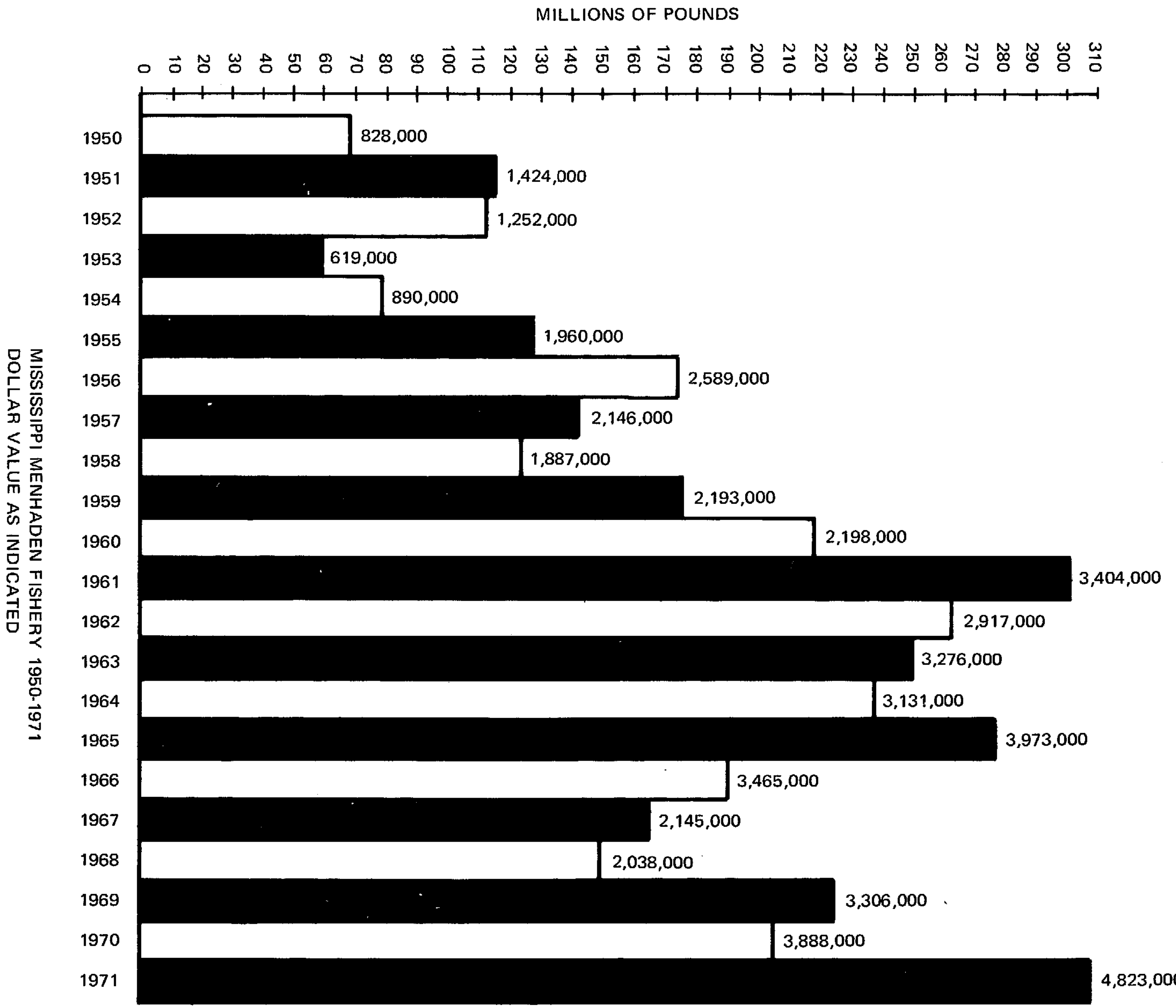


FIGURE 94. MISSISSIPPI MENHADEN FISHERY 1950 - 1971.

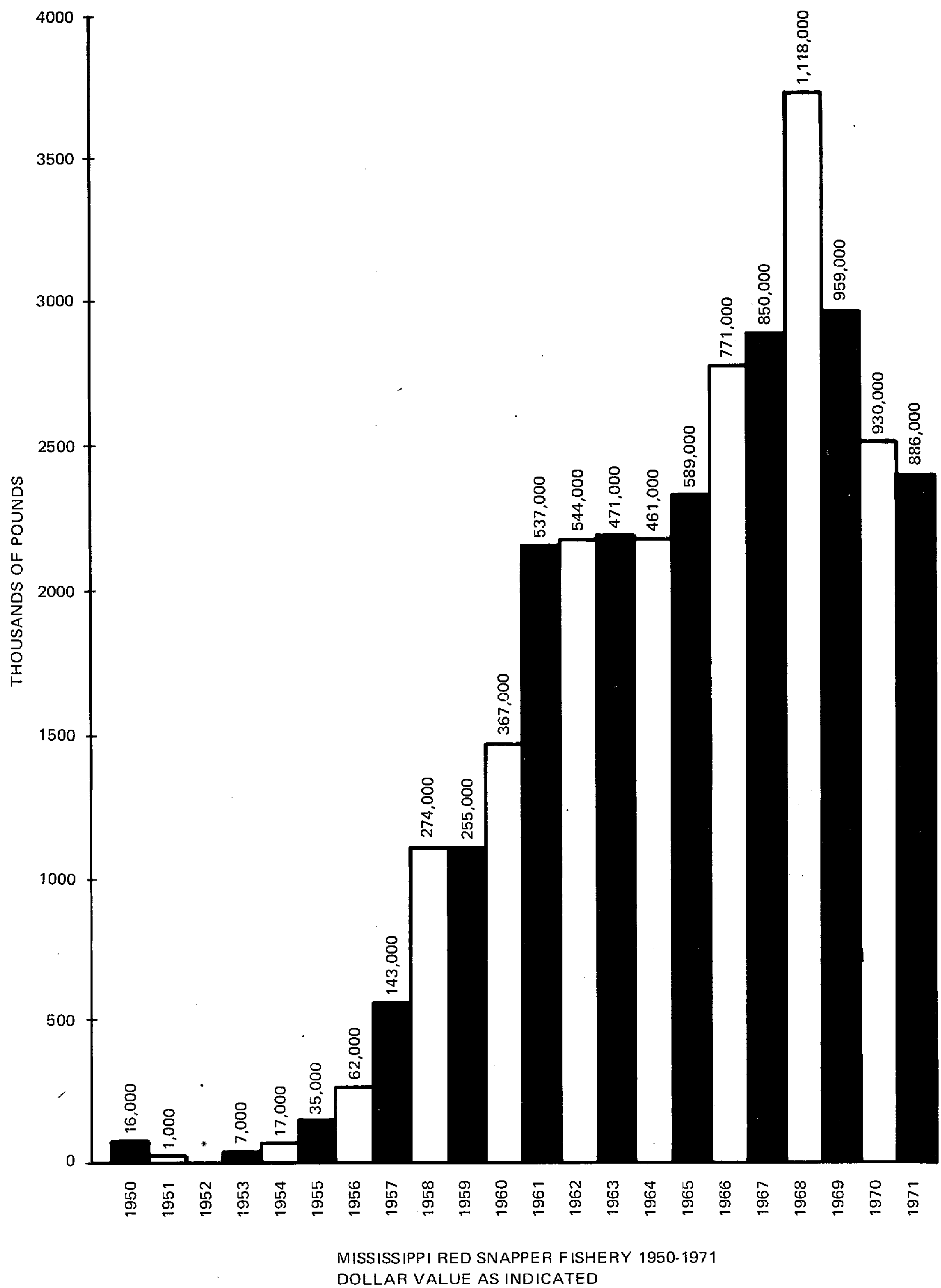
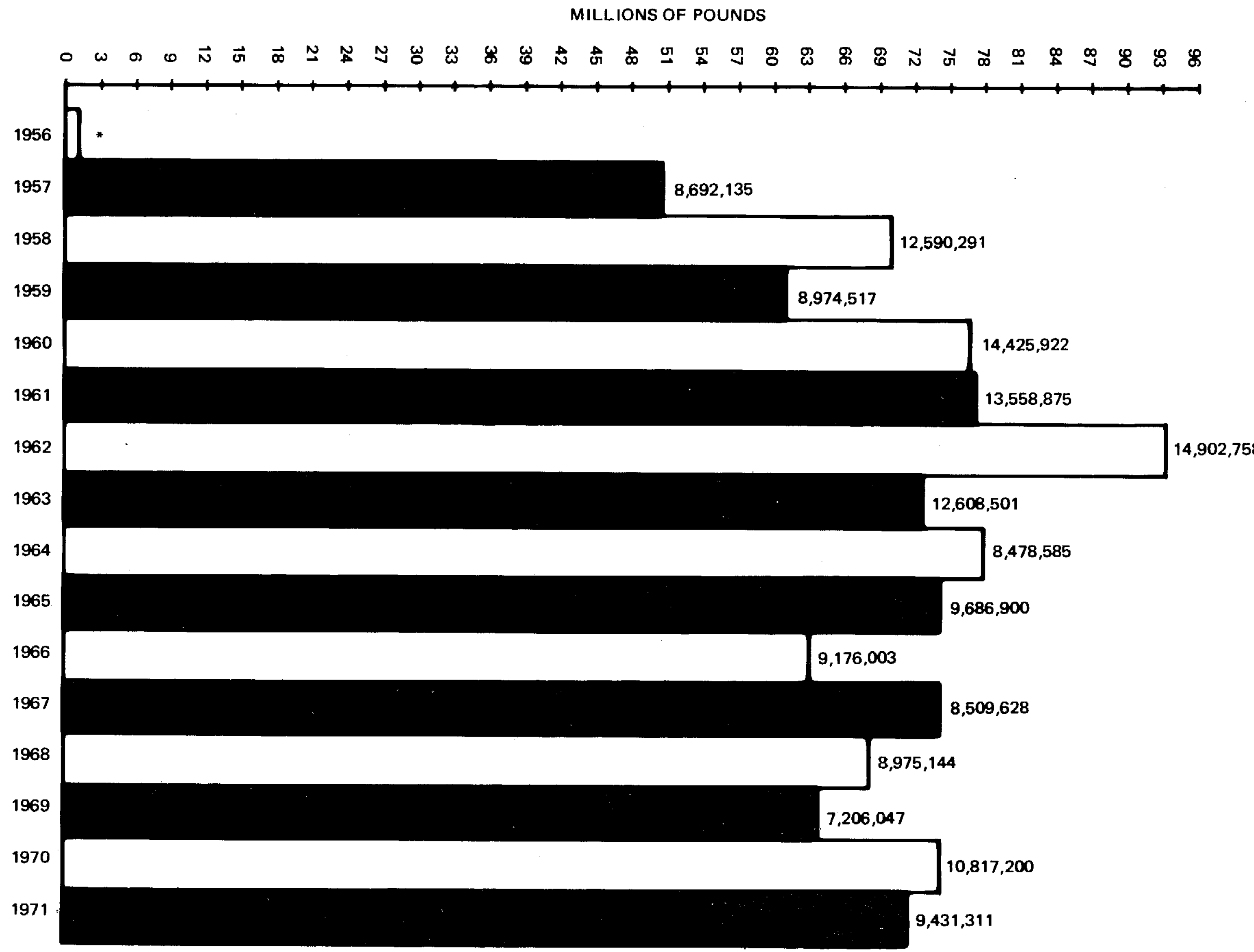
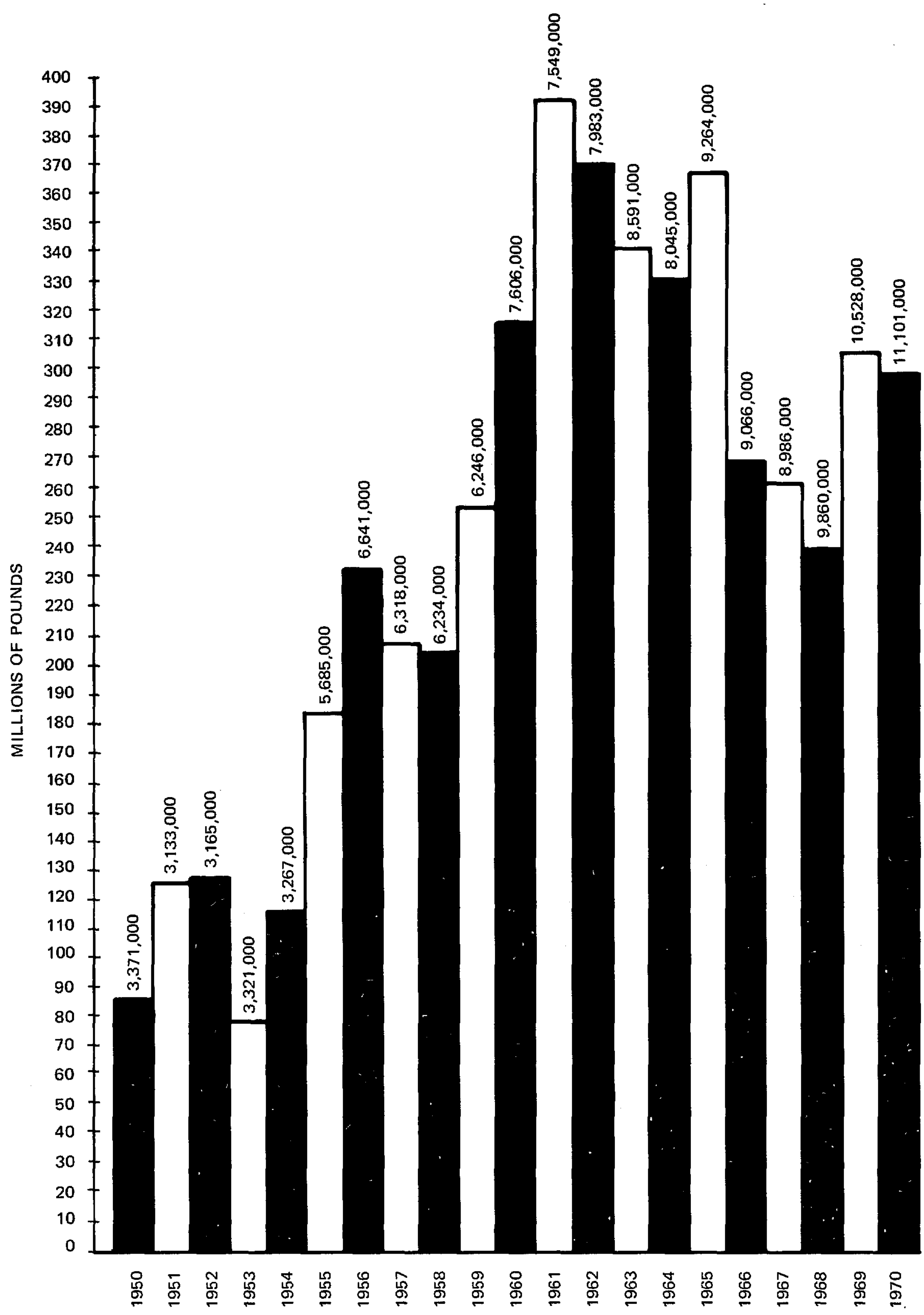


FIGURE 95. MISSISSIPPI RED SNAPPER FISHERY 1950 - 1971.



MISSISSIPPI INDUSTRIAL FISHES
DOLLAR VALUE INDICATED ON CANNED VALUE

FIGURE 96. MISSISSIPPI INDUSTRIAL FISHES 1956 - 1971.



SUMMARY OF MISSISSIPPI COMBINED FISH & SHELLFISH LANDINGS 1950-1970
DOLLAR VALUE AS INDICATED

FIGURE 97. MISSISSIPPI COMBINED FISH AND SHELLFISH LANDINGS 1950 - 1970.

SUMMARY AND RECOMMENDATIONS

The United States, in order to meet the growing energy requirements, will have to increase the importation of foreign crude to supplement its dwindling domestic resources. To deliver this large volume of crude to U. S. refineries expediently and at a reasonable cost will require the utilization of supertankers of 100,000 to 300,000 dead weight tons. At present, these large vessels cannot be accommodated by any port within the continental United States. This means that ports to accommodate such vessels must be developed or U. S. consumers must pay a higher price for energy. Failure of the United States to develop such ports that would supply foreign crude to U. S. refineries may necessitate the importation of higher cost refined petroleum products from foreign refineries.

Monobuoys for off-loading crude from supertankers offer considerable monetary savings and are environmentally preferable to other superport designs. The employment of monobuoys in waters of sufficient natural depth precludes the necessity of costly and environmentally undesirable dredging. Locating monobuoys to service supertankers in the open sea is safer than congesting the onshore ports with the increased small-tanker traffic required to supply the same amount of crude. Furthermore, should a spill occur, an offshore location would allow time for an oil spill contingency plan to be initiated to clean up the oil, whereas, an oil spill nearshore and in semi-confined waters would not allow much time for corrective action to be taken.

Five major water routes are in close proximity to the proposed Superport location, 25 miles south of Pascagoula, Mississippi: Mississippi River, Pearl River, Pat Harrison Waterway, Tennessee-Tombigbee, and Intracoastal Waterway. Also, water in excess of 3,000 feet is less than 30 miles from the site which is an important factor during stormy weather.

The proposed site, unlike areas near the Mississippi River Delta, possesses a stable bottom which is desirable for anchoring monobuoys and supporting pipelines. Areas around the Mississippi Delta, as a result of silt deposition, are unstable due to the continued decay of organic matter in the substratum. This unconsolidated bottom is subject to slumping and turbidity currents.

The Loop Current enters the Gulf of Mexico through the Yucatan Straits and periodically extends northward across the Gulf and over the continental shelf south of Mississippi. The current speed of the core, a relatively high 4.86 knots, would be a positive assist to maritime traffic, especially supertankers, traveling with the current. The Loop Current is also primarily responsible for the difference in the water characteristics of the East and West Gulf. The vertical profiles of dissolved oxygen indicate that the waters of the East Gulf are renewed three times faster than those of the West Gulf. This renewal rate is, of course, environmentally desirable.

A semi-permanent cyclonic eddy exists over the continental shelf south of Mississippi and Alabama. In the event of an oil spill within this eddy structure, the eddy would detain the shoreward migration while cleanup operations were expediently undertaken.

Waves in the proposed site area exceed a height of 12 feet only slightly more than 3 percent of the time with the months of November, December, January, and February accounting for 65 percent of all waves exceeding 12 feet. The sea is relatively calm during the summer months. The winds are primarily northerly during the winter months and from the south and southeast during the summer. Should a spill occur during the winter when the sea state is usually the greatest, the most probable prevailing winds, being from the north, would help keep the spill at sea. Should a spill occur during the summer months with prevailing southerly winds, the sea state is usually calmer allowing a cleanup operation to proceed successfully. There exists, of course, the probability that unfavorable seas and winds could prevail on the occasion of a spill and only an adequately equipped cleanup task force properly deployed could contain the spill.

The pipeline route as proposed in this report is environmentally preferable for a number of reasons. The area east of Bayou Casotte is a fertile nursery area for the young of many important marine species and therefore should be protected from any unnecessary alteration. The route of the pipeline discussed herein would parallel the existing ship channel from west of Petit Bois Island to just east of Bayou Casotte thus eliminating the necessity of extensive dredging of a new access channel for use by a pipe-laying barge and tugs.

This minimizing of dredging likewise reduces the turbid conditions unhealthy for the young of the various species. The pipeline route is also preferable in that the pipe would come ashore where there exists only a narrow fringe of marsh along the shoreline thus minimizing the effect on marsh productivity.

In the event of an oil spill within Mississippi Sound along the proposed pipeline route, the combined actions of the discharge from Pascagoula River and tidal action would serve as a barrier retarding shoreward progression. If, however, an alternate route were selected allowing the pipe to enter and cross land further east of Bayou Casotte, considerable marshland would be affected. Additionally, extensive dredging to construct a channel for a pipe-laying barge and periodic maintenance would be required. Associated with this dredging activity would be the problem of "dredge spoil" placement. With the pipeline so located, an oil spill due to a ruptured pipe would endanger the productive marshland because of the prevailing current patterns. If such a spill should occur during summer months with the prevailing southeast winds, the spill would undoubtedly reach the marsh - the last remaining large productive marsh area in east Mississippi Sound.

The southern boundary of the Citronelle Formation delineates a fault line. While earthquakes have not occurred in the area in a long time, geological investigations reveal that sudden movements cannot be ruled out. The hazard of crossing such a fault is avoided by the pipeline route as proposed within this report which would circumvent the fault to the west.

The proposed monobuoy system is located in the midst of the "Fertile Fisheries Crescent," a highly productive fisheries area. The area has historically produced vast quantities of fisheries products. Over 95 percent of the commercial species caught in the area are, at some phase in their lives, estuarine dependent. The marshes not only provide an abundant supply of food for the marine species but they also provide protection for the young of the species from predators and the more severe environment of the open waters. In the event an oil spill is not contained and reaches shore, the marshes being reached by the oil would show the most damage. The effect of the oil would be to kill the young of the many species directly, and indirectly by destroying the mechanism that converts the organic marsh material to the "detritus" food for the marine species.

While the area south of Mississippi has a significant number of environmentally sound reasons conducive to locating a monobuoy, every precaution should be taken to insure the safety of Mississippi's renewable fisheries resource. Proper navigation, communication, meteorological, and oceanographic instrumentation should be located possibly on the pumping platform to direct tanker traffic and to provide vital information in the event of a spill. A contingency plan with adequate trained personnel and proper equipment to be deployed immediately in the event of a spill should be an integral part of the Superport operation. Placing responsibility for a spill should be secondary to the containment and cleanup operation and should be decided after the cleanup operation is completed. Only in this manner can Mississippi insure the integrity of the marine environment, the esthetics of the coast, and the productivity of both the sport and commercial fisheries while acquiring and benefiting from yet another vital resource.

TABLE XI

MAMMALS OF THE STUDY AREA

Scientific Name	Common Name
Balaena glacialis	Black right whale
Balaenoptera acutorostrata	Minke whale
Balaenoptera borealis	Sei whale
Balaenoptera edeni	Bryde whale
Balaenoptera physalus	Fin whale
Blarina brevicauda	Shorttail shrew
Cryptotis parva	Least shrew
Dasypus novemcinctus	Nine-banded armadillo
Delphinus delphis	Saddleback dolphin
Didelphis marsupialis	Opossum
Eptesicus fuscus	Big brown bat
Feresa attenuata	Pygmy killer whale
Glaucomys volans	Southern flying squirrel
Globicephala macrorhyncha	Blackfish
Grampus griseus	Gray grampus
Kogia breviceps	Pygmy sperm whale
Kogia simus	Dwarf sperm whale
Lasiurus borealis	Red bat
Lasiurus seminolus	Seminole bat
Megaptera novaeangliae	Humpback whale
Mephitis mephitis	Striped skunk
Mesoplodon europaeus	Antillean beaked whale
Monachus tropicalis	Caribbean monk seal
Mus musculus	House mouse
Mustela frenata	Longtail weasel
Mustela vison	Mink
Myocastor coypus	Nutria
Neotoma floridana	Eastern woodrat
Nycticeius humeralis	Evening bat
Odocoileus virginiana	White-tailed deer
Ondatra zibethicus	Muskrat
Orcinus orca	Killer whale
Oryzomys palustris	Rice rat
Peromyscus gossypinus	Cotton mouse
Peromyscus leucopus	White-footed mouse
Peromyscus nuttalli	Golden mouse
Physeter catodon	Sperm whale
Procyon lotor	Raccoon
Pseudorca crassidens	False killer whale
Rattus norvegicus	Norway rat
Rattus rattus	Black rat
Reithrodontomys humulis	Eastern harvest mouse
Scalopus aquaticus	Eastern mole

TABLE XI (Continued)

MAMMALS OF THE STUDY AREA

Scientific Name	Common Name
Sciurus carolinensis	Gray squirrel
Sciurus niger	Fox squirrel
Sigmodon hispidus	Hispid cotton rat
Spilogale putorius	Eastern spotted skunk
Stenella caeruleoalba	Euphrosyne dolphin
Stenella frontalis	Bridled dolphin
Stenella longirostris	Long-snounted dolphin
Stenella paliodon	Spotted dolphin
Steno bredanensis	Rough-toothed dolphin
Sylvilagus aquaticus	Swamp rabbit
Sylvilagus floridanus	Eastern cottontail
Tadarida brasiliensis	Free-tailed bat
Tursiops truncatus	Atlantic bottlenose dolphin
Urocyon cinereoargenteus	Gray fox
Vulpes fulva	Red fox
Zalophus californianus	California sea lion
Ziphius cavirostris	Goose-beaked whale

TABLE XII

REPTILES AND HERPTILES OF THE STUDY AREA

Scientific Name	Common Name
Abastor erythrogrammus	Rainbow snake
Acris crepitans crepitans	Northern cricket frog
Acris gryllus gryllus	Southern cricket frog
Alligator mississipiensis	Alligator
Ambystoma maculatum	Spotted salamander
Ambystoma opacum	Marbled salamander
Ambystoma talpoideum	Mole salamander
Ambystoma texanum	Small mouthed salamander
Ambystoma tigrinum tigrinum	Eastern tiger salamander
Amphiuma means means	Two toed amphiuma
Ancistrodon contortrix contortrix	Southern copperhead
Ancistrodon piscivorous leucostoma	Western cottonmouth moccasin
Anolis carolinensis carolinensis	Green anole
Bufo quercicus	Oak toad
Bufo terrestris terrestris	Southern toad
Bufo valliceps	Gulf coast toad
Bufo woodhousei fowleri	Fowler's toad
Caretta caretta caretta	Atlantic loggerhead turtle
Carphophis amoenus helenae	Midwest worm snake
Cemophora coccinea	Scarlet snake
Chelonia mydas mydas	Atlantic green turtle
Chelydra serpentina serpentina	Common snapping turtle
Cnemidophorus sexlineatus sexlineatus	Six lined race runner
Coluber constrictor priapus	Southern black racer
Crotalus adamanteus	Eastern diamond back rattlesnake
Crotalus horridus atricaudatus	Canebrake rattlesnake
Deirochelys reticularia reticularia	Eastern chicken turtle
Dermochelys coriacea coriacea	Atlantic leatherback turtle
Desmognathus auriculatus	Southern dusky salamander
Desmognathus fuscus conanti	Spotted dusky salamander
Diadophis punctatus stictogenys	Mississippi ringneck snake
Drymarchon corais couperi	Eastern indigo snake
Elaphe guttata guttata	Corn snake
Elaphe obsoleta spiloides	Gray rat snake
Eretmochelys imbricata imbricata	Atlantic hawksbill turtle
Eumeces anthracinus pluvialis	Southern coal skink
Eumeces fasciatus	Five lined skink
Eumeces inexpectatus	Southeastern five lined skink
Eumeces laticeps	Broad headed skink
Eurycea bislineata cirrigera	Southern two lined salamander
Eurycea longicauda guttolineata	Three lined salamander
Farancia abacura reinwardti	Western mud snake
Gastrophryne carolinensis carolinensis	Eastern narrow mouthed toad
Gopherus polyphemus	Gopher tortoise

TABLE XII (Continued)

REPTILES AND HERPTILES OF THE STUDY AREA

Scientific Name	Common Name
Graptemys flavimaculata	Yellow bloched sawback
Graptemys pulchra	Alabama map turtle
Haldea striatula	Rough earth snake
Haldea valeriae elegans	Western earth snake
Hemidactylium scutatum	Four toed salamander
Hemidactylus turcicus turcicus	Mediterranean gecko
Heterodon platyrhinos platyrhinos	Eastern hognose snake
Heterodon simus	Southern hognose snake
Hyla avivoca avivoca	Western bird voiced treefrog
Hyla cinerea cinerea	Green treefrog
Hyla crucifer crucifer	Northern spring peeper
Hyla femoralis	Pine woods tree frog
Hyla gratiosa	Barking treefrog
Hyla squirella	Squirrel treefrog
Hyla versicolor versicolor	Eastern gray treefrog
Kinosternon subrubrum hippocrepis	Mississippi mud turtle
Lampropeltis calligaster rhombomaculata	Mole snake
Lampropeltis doliata doliata	Scarlet king snake
Lampropeltis getulus getulus	Eastern king snake
Lampropeltis getulus holbrooki	Speckled king snake
Lepidochelys kempi	Atlantic ridley
Lygosoma laterale	Ground skink
Macrochelys temmincki	Alligator snapping turtle
Malaclemys terrapin pileata	Mississippi diamondback terrapin
Manculus quadridigitatus	Drawf salamander
Masticophis flagellum flagellum	Eastern coachwhip
Micrurus fulvius fulvius	Eastern coral snake
Natrix cyclopion cyclopion	Green water snake
Natrix erythrogaster flavigaster	Yellow bellied water snake
Natrix fasciata clarki	Gulf salt marsh snake
Natrix fasciata confluens	Broad banded water snake
Natrix fasciata fasciata	Banded water snake
Natrix rhombifera rhombifera	Diamond backed water snake
Natrix rigida sinicola	Glossy water snake
Natrix septemvittata septemvittata	Queen snake
Natrix taxispilota	Brown water snake
Necturus punctatus alabamensis	Alabama waterdog
Necturus punctatus beyeri	Gulf coast waterdog
Notophthalmus viridescens	Louisianensis central newt
Opheodrys aestivus	Rough green snake
Ophisaurus attenuatus longicaudus	Eastern slender glass lizard
Ophisaurus ventralis	Eastern glass lizard
Phrynosoma cornutum	Texas horned lizard
Pituophis melanoleucus lodingi	Black pine snake

TABLE XII (Continued)

REPTILES AND HERPTILES OF THE STUDY AREA

Scientific Name	Common Name
Plethodon glutinosus glutinosus	Slimy falamander
Pseudacris nigrita nigrita	Southern chorus frog
Pseudacris ornata	Ornate chorus frog
Pseudemys alabamensis	Alabama red bellied turtle
Pseudemys concinna mobilensis	Mobile cooter
Pseudemys floridana hoyi	Missouri slider
Pseudemys scripta elegans	Red eared turtle
Pseudemys scripta scripta	Yellow bellied turtle
Pseudotriton montanus flavissimus	Gulf coast mud salamander
Pseudotriton ruber vioscai	Southern red salamander
Rana areolata sevosa	Dusky gopher frog
Rana catesbeiana	Bullfrog
Rana clamitans clamitans	Bronze frog
Rana grylio	Pig frog
Rana hecksheri	River frog
Rana pipiens sphenocephala	Southern leopard frog
Rhadinea flavilata	Yellow lipped snake
Scaphiopus holbrooki holbrooki	Eastern spadefood toad
Sceloporus undulatus undulatus	Southern fence lizard
Siren intermedia intermedia	Eastern lesser siren
Siren lacertina	Greater siren
Sistrurus miliarius barbouri	Dusky pigmy rattlesnake
Sistrurus miliarius streckeri	Western pigmy rattlesnake
Sphaerodactylus notatus	Reef gecko
Sternothaerus carinatus	Razor backed musk turtle
Sternothaerus minor peltifer	Stripe necked musk turtle
Sternothaerus odoratus	Stinkpot
Storeria dekayi wrightorum	Midland brown snake
Storeria occipitomaculata obscura	Southern red bellied snake
Tantilla coronata coronata	Southeastern crowned snake
Terrapene carolina major	Gulf coast box turtle
Thamnophis proximus orarius	Costal ribbon snake
Thamnophis sauritus sauritus	Eastern ribbon snake
Thamnophis sirtalis sirtalis	Eastern garter snake
Trionyx muticus calvatus	Gulf coast smooth softshell
Trionyx spinifer asper	Gulf coast softshell turtle

TABLE XIII

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Accipiter cooperii	Cooper's hawk
Accipiter striatus	Sharp-shinned hawk
Actitis macularia	Spotted sandpiper
Agelaius phoeniceus	Red winged blackbird
Aimophila aestivalis	Bachman's sparrow
Aix sponsa	Wood duck
Ammodramus savannarum	Grasshopper sparrow
Ammospiza caudacuta	Sharp-tailed sparrow
Ammospiza maritima	Seaside sparrow
Anas acuta	Pintail
Anas carolinensis	Green-winged teal
Anas discors	Blue-winged teal
Anas fulvigula	Mottled duck
Anas platyrhynchos	Mallard
Anas rubripes	Black duck
Anas strepera	Gadwall
Anhinga anhinga	Anhinga
Anhinga anhinga leucogaster	Water turkey
Anous stolidus	Noddy tern
Anser albifrons	White-fronted goose
Anthus spinoletta	Water pipit
Anthus spragueii	Sprague's pipit
Aquila chrysaetos	Golden eagle
Archilochus colubris	Ruby throated hummingbird
Ardea herodias	Great blue heron
Arenaria interpres	Ruddy turnstone
Asio flammeus	Short-eared owl
Aythva affinis	Lesser scaup duck
Aythya americana	Redhead
Aythya collaris	Ring-necked duck
Aythya marila	Greater scaup
Aythya valisineria	Canvasback
Bartramia longicauda	Upland sandpiper
Bombycilla cedrorum	Cedar waxwing
Botaurus lenthginosus	American bittern
Branta canadensis canadensis	Canada goose
Bubo virginianus	Great horned owl
Bubuleus ibis	Cattle egret
Bucephala albeola	Bufflehead
Bucephala clangula	Common goldeneye
Buted harlani	Harlan's hawk

TABLE XIII (Continued)

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Buted jamaicensis	Red-tailed hawk
Buted lineatus	Red shouldered hawk
Buted platypterus	Broad-winged hawk
Butorides virescens	Green heron
Calidris canutus	Red knot
Capella gallinago	Common snipe
Caprimulgus carolinensis	Chuck-Will's widow
Caprimulgus vociferus	Whip-poor-will
Carpodacus purpureus	Purple finch
Casmerodius albus	Common egret
Cassidix mexicanus	Boat tailed grackle
Cathartes aura	Turkey vulture
Catoptrophorus semipalmatus	Willet
Centurus carolinus	Red-bellied woodpecker
Certhia familiaris	Brown creeper
Chaetura pelagica	Chimney swift
Charadrius alexandrinus	Snowy plover
Charadrius melodus	Piping plover
Charadrius semipalmatus	Semipalmated plover
Charadrius vociferus vociferus	Killdeer
Charadrius wilsonia	Wilson's plover
Chen caerulescens	Blue goose
Chen hyperborea	Snow goose
Chlidonias niger	Black tern
Chondestes grammacus	Lark sparrow
Chordeiles minor	Common night hawk
Circus cyaneus hudsonius	Marsh hawk
Cistothorus platensis	Short-billed marsh wren
Clangula hyemalis	Oldsquaw
Coccyzus americanus americanus	Yellow billed cuckoo
Coccyzus erythropthalmus	Black-billed cuckoo
Colaptes auratus	Yellow shafted flicker
Colinus virginianus	Bobwhite
Columbigallina passerina	Ground dove
Contopus virens	Eastern wood pewee
Coragyps atratus	Black vulture
Corvus brachyrnynchos	Common crow
Corvus ossifragus	Fish crow
Coturnicops noveboracensis	Yellow rail
Crocethia alba	Sanderling
Crotophaga sulcirostris	Groove-billed ani
Cyanocitta cristata	Blue jay

TABLE XIII (Continued)

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Dendrocopos borealis	Red-cockaded woodpecker
Dendrocopos pubescens	Downy woodpecker
Dendrocopos villosus	Hairy woodpecker
Dendroica caerulescens	Black-throated blue warbler
Dendroica castanea	Bay-breasted warbler
Dendroica cerulea	Cerulean warbler
Dendroica coronata	Myrtle warbler
Dendroica discolor	Prairie warbler
Dendroica dominica	Yellow-throated warbler
Dendroica fusca	Blackburnian warbler
Dendroica magnolia	Magnolia warbler
Dendroica nigrescens	Black-throated gray warbler
Dendroica palmarum	Palm warbler
Dendroica pensylvanica	Chestnut-sided warbler
Dendroica petechia	Yellow warbler
Dendroica pinus	Pine warbler
Dendroica striata	Blackpoll warbler
Dendroica tigrina	Cape may warbler
Dendroica townsendi	Townsend's warbler
Dendroica virens	Black-throated green warbler
Dichromanassa rufescens	Reddish egret
Dolichonyx orvzivorus	Bobolink
Dryocopus pileatus	Pileated woodpecker
Dumetella carolinensis	Gray catbird
Elanoides forficatus	Swallow-tailed kite
Empidonax flaviventris	Yellow-bellied flycatcher
Empidonax minimus	Least flycatcher
Empidonax traillii	Traill's flycatcher
Empidonax virescens	Acadian flycatcher
Ereunetes mauri	Western sandpiper
Ereunetes pusillus	Semipalmated sandpiper
Erolia alpina	Dunlin
Erolia bairdii	Baird's sandpiper
Erolia fuscicollis	White-rumped sandpiper
Erolia melanotos	Pectoral sandpiper
Erolia minutilla	Least sandpiper
Eudocimus albus	White ibis
Euphagus carolinus	Rusty blackbird
Euphagus cyanocephalus	Brewer's blackbird
Falco columbarius	Merlin
Falco peregrinus	Peregrine falcon

TABLE XIII (Continued)

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Falco sparverius	American kestrel
Florida Caerulea	Little blue heron
Fregata magnificens	Magnificent frigatebird
Fulica amiercana	American coot
Gallinula chloropus	Common gallinule
Gavia immer	Common loon
Gavia stellata	Red-throated loon
Gelochelidon nilotica	Gull-billed tern
Geothlypis trichas	Yellowthroat
Grus canadensis	Florida sandhill crane
Guiraca caerulea	Blue gosbeak
Haematopus palliatus	American oystercatcher
Halioeetus leucocephalus	Southern bald eagle
Helmitheros vermivorus	Worm-eating warbler
Hesperiphona vespertina	Evening grosbeak
Himantopus mexicanus	Black-necked stilt
Hirundo rustica	Barn swallow
Hydranassa tricolor	Louisiana heron
Hydroprogne caspia	Caspian tern
Hylocichla fuscescens	Veery
Hylocichla guttata	Hermit thrush
Hylocichla minima	Gray-cheeked thrush
Hylocichla mustelina	Wood thrust
Hylocichla ustulata	Swainson's thrush
Icterus galbula	Northern oriole
Icterus spurius	Orchard oriole
Icteria virens	Yellow-breasted chat
Ictinia misisippiensis	Mississippi kite
Iridoprocne bicolor	Tree swallow
Ixobrychus exilis	Least bittern
Junco hyemalis	Slate colored junco
Lanius ludovicianus	Loggerhead shrike
Larus argentatus	Herring gull
Larus atricilla	Laughing gull
Larus delawarensis	Ring-billed gull
Larus hyperboreus	Glaucous gull
Larus philadelphis	Bonaparte's gull
Larus pipixcan	Franklin's gull
Laterallus jamaicensis	Black rail
Leucophoyx thula	Snowy egret
Limnodromus griseus	Short-billed dowitcher
Limnothlypis swainsonii	Swainson's warbler

TABLE XIII (Continued)

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Limosa fedoa	Marbled godwit
Lophodytes cucullatus	Hooded merganser
Mareca americana	American wigeon
Megaceryle alcyon alcyon	Belted kingfisher
Melanerpes erythrocephalus	Red headed woodpecker
Melanitta deglandi	White-winged scoter
Melanitta perspicillata	Surf scoter
Meleagris gallopavo	Wild turkey
Melpspiza georgiana	Swamp sparrow
Melospiza lincolnii	Lincoln's sparrow
Melospize melodia	Song sparrow
Mergus merganser	Common merganser
Mergus serrator	Red-breated merganser
Micropalama himantopus	Stilt sandpiper
Mimus polyglottos	Mockingbird
Mniotilta varia	Black-and-white warbler
Molothrus ater	Brown-headed cowbird
Morus bassanus	Gannet
Muscivora forficata	Scissor-tailed flycatcher
Myiarchus crinitus	Great crested flycatcher
Numenius americanus	Long-billed curlew
Numenius phaeopus	Whimbrel
Nuttallornis borealis	Olive-sided flycatcher
Nyctanassa violacea	Yellow crowned night heron
Nycticorax nycticorax hoactli	Black crowned night heron
Oporornis formosus	Kentucky warbler
Oporornis philadelphia	Mourning warbler
Otus asio	Screech owl
Oxyura jamaicensis	Ruddy duck
Pandion halioetus carolinensis	Osprey
Parula americana	Northern parula
Parus bicolor	Tufted titmouse
Parus carolinensis	Carolina chickadee
Passer domesticus	House sparrow
Passerculus sandwichensis	Savannah sparrow
Passerella iliaca	Fox sparrow
Passerherbulus caudacutus	Leconte's sparrow
Passerherbulus henslowii	Henslow's sparrow
Passerina ciris	Painted bunting
Passerina cyanea	Indigo bunting
Pelecanus erythrorhynchos	White pelican
Pelacanus occidentalis	Brown pelican
Petrochelidon pyrrhonota	Cliff swallow

TABLE XIII (Continued)

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Phalacrocorax auritus	Double crested cormorant
Pheucticus ludovicianus	Rose-breated grosbeak
Pheucticus melanocephalus	Black-headed grosbeak
Philohela minor	American woodcock
Pipilo erythrophthalmus	Rufous sided towhee
Piranga ludoviciana	Western tanager
Piranga olivacea	Scarlet tanager
Pirange rubra	Summer tanager
Plegadis chihi	White-faced ibis
Plegadis falcinellus	Glossy ibis
Pluvialis dominica	American golden plover
Podiceps auritus	Horned grebe
Podiceps caspicus	Eared grebe
Podilymbus podiceps	Pied billed grege
Polioptila caerulea	Blue-gray gnatcatcher
Pooecetes gramineus	Vesper sparrow
Porphyrula martinica	Purple gallinule
Porzana carolina	Sora
Progne subis	Purple martin
Protonotaria citrea	Prothonotary warbler
Pyrocephalus rubinus	Vermilion flycatcher
Quiscalus quiscula	Common grackle
Rallus elegans elegans	King rail
Rallus limicola	Virginia rail
Rallus longirostris	Clapper rail
Recurvirostra americana	American avocet
Regulus calendula	Ruby-crowned kinglet
Regulus satrapa	Golden-crowned kinglet
Richmondena cardinalis	Cardinal
Riparia riparia	Bank swallow
Rissa tridactyla	Black-legged kittiwake
Rynchops nigra	Black skimmer
S. hirundo hirundo	Common tern
Sayornis phoebe	Eastern phoebe
Sayornis saya	Say's phoebe
Seiurus aurocapillus	Ovenbird
Seiurus motacilla	Louisiana waterthrush
Seiurus noveboracensis	Northern waterthrush
Setophaga ruticilla tricolora	American redstart
Sialia sialis sialis	Eastern bluebird
Sitta canadensis	Red-breasted nuthatch

TABLE XIII (Continued)

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Sitta carolinensis	White-breasted nuthatch
Sitta pusilla	Brown-headed nuthatch
Somateria spectabilis	King eider
Spatula clypeata	Shoveler
Speotyto cunicularia	Burrowing owl
Sphyrapicus varius	Yellow-bellied sapsucker
Spinus pinus	Pine siskin
Spinus tristis	American goldfinch
Spiza americana	Dickcissel
Spizella pallida	Clay-colored sparrow
Spizella passerina	Chipping sparrow
Spizella pusilla	Field sparrow
Squatarola squatarola	Black-bellied plover
Steganopus tricolor	Wilson's phalarope
Stelgidopteryx ruficollis	Rough-winged swallow
Stercorarius parasiticus	Parasitic jaeger
Sterna albifrons	Least tern
Sterna forsteri	Foster's tern
sterna hirundo	Common tern
Strix varia	Barred owl
Sturnella magna	Eastern meadowlark
Sturnella neglecta	Western meadowlark
Sturnus vulgaris vulgaris	Starling
Tachycineta bicolor	Tree swallow
Telmatodytes palustris	Long-billed marsh wren
Thalasseus maximus	Royal tern
Thalasseus sandvicensis	Sandwich tern
Thryomanes bewickii	Bewick's wren
Thryothorus ludovicianus	Carolina wren
Totanus flavipes	Lesser yellowlegs
Totanus melanoleucus	Greater yellowlegs
Toxostoma rufum	Brown thrasher
Tringa solitaria	Solitary sandpiper
Troglodytes aedon	House wren
Troglodytes troglodytes	Winter wren
Trynoites subruficollis	Buff-breasted sandpiper
Turdus migratorius	Robin
Tyrannus dominicensis	Gray kingbird
Tyrannus tyrannus	Eastern kingbird
Tyrannus verticalis	Western kingbird
Tyto alba	Barn owl

TABLE XIII (Continued)

BIRDS OF THE STUDY AREA

Scientific Name	Common Name
Vermivora bachmanii	Bachman's warbler
Vermivora celata	Orange-crowned warbler
Vermivora chrysoptera	Golden-winged warbler
Vermivora peregrina	Tennessee warbler
Vermivora pinus	Blue-winged warbler
Vermivora ruficapilla	Nashville warbler
Vireo bellii	Bell's vireo
Vireo flavifrons	Yellow-throated vireo
Vireo griseus	White-eyed vireo
Vireo olivaceus	Red-eyed vireo
Vireo philadelphicus	Philadelphia vireo
Vireo solitarius	Solitary vireo
Wilsonia canadensis	Canada warbler
Wilsonia citrina	Hooded warbler
Wilsonia pusilla	Wilson's warbler
Xanthocephalus xanthocephalus	Yellow-headed blackbird
Zenaida asiatica	White-winged dove
Zenaidura macroura	Mourning dove
Zonotrichia albicollis	White throated sparrow
Zonotrichia leucophrys	White-crowned sparrow
Zonotrichia querula	Harris' sparrow

TABLE XIV

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Ablennes hians	Flat needlefish
Abra aequalis	Common Atlantic abra
Abra lioca	Dalls's little abra
Abudefduf saxatilis	Sergeant major
Abyloposis eschscholtzi	
Abylopsis tetragona	
Acanthocybium solanderi	Wahoo
Acartia tonsa	Common copepod
Acetes americanus	Sergistio shrimp
Acetes carolinae	
Achirus lineatus	Striped sole
Acipenser oxyrhynchus	Atlantic sturgeon
Acteon punctostriatus	
Adinia xenica	Diamond killifish
Aegathoa oculata	
Aequipecten gibbus	Calico scallop
Aequipecten irradians concent	Atlantic bay scallop
Aetobatus narinari	Soptted eagle ray
Agalma okeni	
Aglaura hemistoma	
Ahlia egmontis	Worm eel
Aiptasia pallida	Anemone
Alabina cerithidioides	
Albunea sp.	Mole crab
Alectis crinitus	Thread fish
Alepisaurus ferox	Longnose lancetfish
Alpheus heterochaelis	
Alopias vulpinus	Thresher shark
Alosa alabamae	Alabama shad
Alosa chrysochloris	Skipjack
Alosa sapidissima	American shad
Aluterus hewdeloti	Dotterel filefish
Aluterus monoceros	Unicorn filefish
Aluterus schoepfi	Orange filefish
Aluterus scripta	Longtail filefish
Amia calva	Bowfin
Ampelisca abdita	
Ampelisca holmesii	
Amphicteis gunneri	Polychaete
Amphinema dinema	
Amphithoe longimanus	
Amphithoe validida	
Amphitrite ornata	Polychaete

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Amygdalum papyria	
Anachis avara	Greedy dove, shell gastropod
Anachis obesa	Fat dove shell, mud snail
Anadara brasiliana	Incongruous ark
Anadara transversa	Transverse ark
Anasimus latus	
Anchoa cubana	Cuban anchovy
Anchoa hepsetus	Striped anchovy
Anchoa lamprotaenia	Bigeye anchovy
Anchoa lyolepis	Dusky anchovy
Anchoa mitchilli	Common anchovy
Anchoa nasuta	Longnose anchovy
Anchoviella perfasciata	Flat anchovy
Ancylopsetta dilecta	Three eyed flounder
Ancylopsetta quadrocellata	Ocellated flounder
Andara ovalis	Blook ark
Anguilla rostrata	American eel
Anomalocardia cuneimeris	Wedge-shaped venus
Anomia simplex	Common jingle shell
Antennarius ocellatus	Ocellated frogfish
Antennarius radiosus	Singlespot frogfish
Antennarius scaber	Splitlure frogfish
Aplodinotus grunniens	Freshwater drum
Aplysia willcoxi	Willcox's sea-hare
Apogonidae	Cardinal fishes
Aprionodon isodon	Finetooth shark
Arbacia punctulata	Sea urchin
Arca zebra	Turkey wing
Archosargus probatocephalus	Sheepshead
Arenaeus cribrarius	Swimming crab
Arenicola caroledna	Polychaete
Arenicola cristata	Bloodworm
Argentina atriata	Argentine
Argulus fuscus	
Ariomma regulus	Spotted drift fish
Arius felis	Sea catfish
Armina tigrina	Tiger nudibranch
Astrangia astreiformis	Stony star coral
Astrangia solitaria	Stony coral
Astropecten articulatus	Starfish
Astropecten duplicatus	
Astroscopus y-graecum	Southern stargazer

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Atrina seminuda	Half-spined pen shell
Atrina serrata	Saw-toothed pen shell
Atylus minikai	
Aulostomus maculatus	Trumpet fish
Aurellia aurita	Common white jelly fish
Auxis thazard	Frigate mackeral
Axiothella muscosa	Polychaete
Bagre marinus	Gafftopsail catfish
Bairdiella chrysura	Silver perch
Balanus amphitrite	Barnacles
Balanus eburneus	Ivory barnacle
Balanus improvisus	Barnacles
Balanus tintinnabulum	Acorn barnacle
Balistes capriscus	Gray triggerfish
Bankia gouldi	
Barnea costata	
Barnea truncata	
Bascanichthys scuticaris	Whip eel
Bascanichthys teres	Sooty eel
Bassia bassensis	
Batea catherinensis	
Bathygobius sporator	Frillfin goby
Bellator militaris	Horned sea robin
Bembrops gobioides	Clear head
Benthodesmus tenuis	Benthodesmus
Benthopagurus cokeri	
Beroe ovata	Oval comb jelly
Bittium varium	Variable bittium, snail
Blennius marmoreus	Seaweed blenny
Bollmannia communis	Ragged goby
Bothus ocellatus	Eyed flounder
Bougainvillia carolinensis	
Bougainvillia frondosa	
Branchidontes exustus	Bivalves
Branchidontes recurvus	Mussel
Branchiostoma caribaeum	Caribbean lancelet
Branchipus sp.	Fairy shrimp
Bregmaceros atlanticus	Antenna codlet
Brevoortia gunteri	Small-scaled menhaden
Brevoortia patronus	Gulf menhaden
Brevoortia smithi	Yellowfin menhaden
Brotula barbata	Brotula
Bugula sp.	Bryozoan

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Bugula neritina	Treelike moss animal
Bulla striata	
Bunodactis	
Bursatella leachi	Ragged sea hare
Busycon perversum	Perverse whelk
Busycon spiratum	Prosobranch snail, pear whelk
Caecum cooperi	
Caecum cf. glabrum	
Caecum nitidum	Snail
Caecum pulchellum	Snail
Calamus actifrons	Grass porgy
Calappa springeri	
Calliactis polypus	
Calliactris tricolor	Common sea anemone
Callianassa jamaicense	Louisiana mud shrimp
Callianassa major	Mud shrimp
Callinectes sapidus	Common blue crab, blue edible cr
Callinectes similis	
Callista eucymata	Glory-of-the-seas venus
Callocardia texasiana	
Cancellaria reticulata	Common nutmeg
Cantharus cancellarius	Cancellate cantharus
Canthidermis maculatus	Rough triggerfish
Caprella carolinensis	
Caranx bartholomaei	Yellow jack
Caranx crysos	Blue runner
Caranx hippos	Common jack
Caranx latus	Horse-eye jack
Caranx ruber	Bar jack
Carcharhinus acronotus	Blacknose shark
Carcharhinus leucas	Bull shark
Carcharhinus limbatus	Blacktip shark
Carcharhinus longimanus	White-tipped shark
Carcharhinus milberti	Sandbar shark
Carcharhinus obscurus	Dusky shark
Cardita floridana	Bivalves
Carinogammarus mucronatus	Amphipod
Carpiodes carpio	River carpsucker
Carpiodes cyprinus	Quillback
Catharus tinctus	Prosobranch snail
Caulolatilus cyanops	Blackline tilefish
Cavolina longirostris	
Centropristis melana	Southern sea bass

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Centropristis ocyurus	Bank sea bass
Centropristis philadelphica	Rock sea bass
Centropristis striata	Black sea bass
Ceratocymba leukartii	
Ceratocymba sagittata	
Cerebratulus lacteus	Large ribbon worm
Cerithiopsis greeni	
Cerithium variable	Herbivorus snail
Chaenobryttus gulosus	Warmough
Chaetodipterus faber	Atlantic spadefish
Chaetodon capistratus	Four eye butterflyfish
Chaetodon ocellatus	Spotfin butterflyfish
Chaetodon sedentarius	Reef butterflyfish
Chaetopterus variopedatus	Polychaete
Chama congregata	
Chasmocarcinus mississippiensis	
Chasmodes bosquianus	Banded blenny
Chasmodes saburrae	Florida blenny
Chaunax pictus	Painted gaper
Chelonibia patula	Crab barnacle
Chelophyes appendiculata	
Chilomycterus schoepfri	Striped burrfish
Chione cancellata	Cross-barred venus, bivalves
Chione grus	Gray pygmy venus
Chione intapurpurea	Cribrara venus
Chiropsalmus quadrumanus	
Chloropthalmus chalybeius	Mottled greeneye
Chloropthalmus truculentus	Truculent greeneye
Chleroscombrus chrysurus	Bumber, atlantic
Chrysaora quinquecirrha	
Chthamulus fragilis	Barnacles
Cistenides gouldii	
Citharichthys macrops	Spotted whiff
Citharichthys spilopterus	Bay whiff
Cleantis sp.	Isopod
Clibanarius vittatus	Striped hermit crab
Cliona celata	Sulphur sponge
Clione vastifica	Sponge
Clypeaster	
Conchoderma virgatum	
Congrina flava	Yellow conger eel
Corambella baratarioe	
Corbicula contracta	Bivalves

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Corbula sp.	
Cordagalma cordiformis	
Corophium acherusicum	
Corophium louisianum	
Coryphaena equisetis	Pompano dolphin
Coryphaena hippurus	Dolphin
Crassinella lunulata	Lunate crassinella
Crassostrea virginica	Eastern oyster
Crepidula convexa	Convex slipper-shell
Crepidula fornicata	Common atlantic slipper-shell
Crepidula maculosa	
Crepidula plana	Eastern white slipper-shell
Creseis acicula	Straight needle pteropod
Cryptotomus auropunctatus	Parrotfish
Cubiceps athenae	Cigarfish
Cumingia tellinoides	
Cuna dalli	Moore's cuna
Cunina octonaria	
Cunina peregrina	
Cyanea capillata	
Cyathura polita	Isopod
Cyclinella tenuis	Burrowing bivalves
Cyclopsetta chittendeni	Chittenden's flounder
Cyclopsetta fimbriata	Spotfin flounder
Cyclostremiscus trilix	
Cylichna bidentata	
Cylisticus convexus	Convex sowbug
Cymadusa compta	
Cymadusa filosa	
Cynoscion arenarius	White weakfish
Cynoscion nebulosus	Speckled weakfish
Cynoscion nothus	Sand weakfish
Cyprinodon variegatus	Sheepshead minnow, killifish
Cypselurus cyanopterus	Bearded flying fish
Cypselurus heterurus	Four wing flying fish
Cyrtopleura costata	Burrowing bivalves
Cytaeis tetrastyla	
Dactylometra quinquecirrha	Sea nettle
Dactylopterus volitans	Flying gurnard
Dactyloscopus tridigitatus	Gill
Dasyatis americana	American sting ray
Dasyatis centroura	Roughtail sting ray
Dasyatis sabina	Atlantic stingray

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Dasyatis sayi	Say's sting ray
Dentalium eboreum	
Decapterus punctatus	Round scad
Dentalium texasianum	
Dibranchus atlanticus	Two-gilled batfish
Dinocardium robustum	Giant atlantic cockle
Diodon holocanthus	Balloonfish
Diodora cayenensis	Little or cayenne keyhole limpe
Diopatra cuprea	Polychaete
Diphyes bojani	
Diphyes dispar	
Diplectrum bivittatum	Dwarf sand perch
Diplectrum formosum	Sand perch
Diplodonta punctata	Common atlantic diplodon
Diplodus holbrooki	Spottail pinfish
Diplothyra smithii	
Dipurena ophiogaster	
Donax obesus	Flat wedge clam
Donax variabilis	Coquina shell
Doris verrucosa	
Dormitator maculatus	Fat sleeper
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Doryteuthis plei	
Dosinia discus	Disk dosinia
Drilonereis sp.	Polychaete
Dromidia antillensis	Crustaceans
Echeneis naucrates	Sharksucker
Echinaster modestus	
Eirene pyramidalis	
Eirene viridula	
Elagatis bipinnulata	Rainbow runner
Eleotris pisonis	Spinycheek sleeper
Elops saurus	Ladyfish, tenpounder
Emerita portoricensis	Puerto Rican mole crab
Emerita talpoida	Baitbug, sandbug
Emerita talpoides	Mole crab
Encope michelini	Sand dollar
Engyophrys senta	Spiny flounder
Enneagonium hyalinum	
Ensis minor	Miniature jack-knife clam
Epinephelus drummondhayi	Speckled hind
Epinephelus itajara	Jew fish

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Epinephilus morio	Red grouper
Epinephelus nigritus	Warsaw grouper
Episcynia multicarinata	
Epitonium angulatum	
Epitonium rupiculum	Rock-inhabiting peg
Equetus acuminatus	High hat
Equetus lanceolatus	Jackknife fish
Ericthonius brasilensis	
Erimyzon tenuis	Sharpfin chubscuker
Erotelis smaragdus	Emerald sleeper
Ervillia concentrica	
Esox americanus	redfin pickerel
Esox niger	Chain pickerel
Etropus crossotus	Fringed flounder
Etropus microstomus	Smallmouth flounder
Etropus rimosus	Gray flounder
Etrumeus teres	Round herring
Eubranchus sp.	
Eucalanus attenuatus	
Euceramus praelongus	Sandbug
Eucinostomus argenteus	Spotfin mojarra
Eucinostomus gula	Silver jenny
Eudoxoides mitra	
Eudoxoides spiralis	
Euglandina rosea	Rosy euglandina
Eulamia obscurus	Dusky shark
Euleptorhamphus velox	Flying half beak
Euphysora gracilis	
Eurycerus lamellatus	Muller's waterflea
Eurypanopeus depressus	Crustaceans
Euthynnus alletteratus	Little tunny
Euthynnus pelamis	Skipjack tuna
Eutima mira	
Eutima variabilis	
Evorthodus lyricus	Lyre goby
Fasciolaria hunteria	Banded tulip
Fasciolaria tulipa	Snail
Finella dubia	Dubious finella
Fistularia tabacaria	Cornet fish
Fundulus chrysotus	Golden topminnow
Fundulus confluentus	Marsh killifish
Fundulus grandis	Gulf killifish
Fundulus heteroclitus	Gulf mummichog

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Fundulus jenkinsi	Saltmarsh topminnow
Fundulus notatus	Blackstripe topminnow
Fundulus notti	Starhead topminnow
Fundulus olivaceus	Blackspotted topminnow
Fundulus pulvereus	Bayou killifish
Fundulus similis	Longnose killifish
Galeocerdo cuvieri	Tiger shark
Gambusia affinis	Mosquitofish
Gammarus locusta	Seaweed hopper
Gastropteron rubrum	
Gastrosaccus dissimilis	
Gemma gemma	
Geryonia proboscidalis	
Ginglymostoma cirratum	Nurse shark
Glycera dibranchiata	Proboscis bloodworm
Gnathagnus egregius	Freckled stargazer
Gobiesox strumosus	Skilletfish, cling fish
Gobioides broussonneti	Violet goby
Gobionellus boleosoma	Darter goby
Gobionellus gracillimus	Slim goby
Gobionellus hastatus	Sharptail goby
Gobionellus oceanicus	Highfin goby
Gobionellus shufeldti	Freshwater goby
Gobionellus stigmaticus	Spotted goby
Gobiosoma bosci	Naked goby
Gobiosoma longipala	Twoscale goby
Gobiosoma robustum	Code goby
Graptemys flavimaculata	
Gunterichthys longipenis	Gold brotula
Gymnachirus melas	Naked sole
Gymnachirus texae	Fringed sole
Gymnothorax moringa	Spotted moray
Gymnothorax nigromarginatus	Blackedge moray
Gymnothorax ocellatus	Ocellated moray eel
Gymnura micrura	Smooth butterfly ray
Haemulon carbonarium	Caesar grunt
Haemulon plumieri	White grunt
Haemulon sciurus	Bluestriped grunt
Halichoeres radiatus	Puddingwife
Haliclona sp.	Deadman fingers
Halieutichthys aculeatus	Deep-sea batfish
Haminoea antillarum	Globose paper bubble
Haminoea succinea	Snail

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Haploscoloplos fragilis	Polychaete
Harengula pensacolae	Sardine
Haustorius spp.	Amphipods
Haustorius mexicanus	
Hemanthias leptus	Longtail bass
Hemanthias vivanus	Red barbier
Hemiaegina minuta	
Hemicaranx amblyrhynchus	Bluntnose jack
Hemipteronotus novacula	Pearly razorfish
Hemiramphus balao	Balao
Hemiramphus brasiliensis	Ballyhod
Heterandria formosa	Least killifish
Hepatus epheliticus	Box crab
Hippocampus erectus	Lined seahorse
Hippocampus zosterae	Dwarf seahorse
Hippolyte pleuracantha	
Hippolyte zostericola	
Hippopodius hippopus	
Histrio histrio	Sargassumfish
Holocentrus ascenionis	Squirrel fish
Hoplunnis macrurus	Silver conger
Hybocodon forbesi	
Hybognathus hayi	Cypress minnow
Hybognathus nuchalis	Silvery minnow
Hybopsis aestivalis	Speckeled chub
Hybopsis amblops	Big eye chub
Hydractinia echinata	Hydroid
Hydroides hexagonus	Polychaete
Hyperoglyphe perciformis	Barrel fish
Hypleurochilus geminatus	Crested blenny
Hyporhamphus unifasciatus	Halfbeak
Hypsoblennius hentzi	Feather blenny
Hypsoblennius ionthas	Freckled blenny
Ichthyomyzon gagei	Southern brook lamprey
Ictalurus furcatus	Blue catfish
Ictalurus melas	Black bullhead
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Ictiobus bubalus	Smallmouth buffalo
Ictiobus niger	Black buffalo
Ircinia fasciculata	Sponge
Istiophorus platypterus	Sailfish
Isurus oxyrinchus	Short fin mako

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Kathetostoma albigutta	Lancer stargazer
Kellia suborbicularis	Thomson's lepton
Kurtziella cerinella	
Kyphosus sectatrix	Bermuda chub
Labidesthes sicculus	Brook silverside
Labidocera aestiva	
Labiosa plicatella	Sailor's ear
Lachnolaimus maximus	Hogfish
Lactophrys quadricornis	Scrawled cowfish
Lactophrys trigonus	Trunkfish
Laeonereis culveri	Polychaete
Laevicardium laevigatum	Common egg cockle
Laevicardium mortoni	Morton's egg cockle
Lagocephalus laevigatus	Smooth puffer
Lagodon rhomboides	Pinfish
Lamna nasus	Porbeagle
Lampetra gepyptera	Least brook lamprey
Laodicea undulata	
Larimus fasciatus	Banded drum
Latreutes fucorum	
Latreutes parvulus	
Leander tenuicornis	Sargassum shrimp
Lensia campanella	
Lensia subtilis	
Leiostomus xanthurus	Spot
Lepidactylus burbanki	
Lepisosteus oculatus	Spotted gar
Lepisosteus osseus	Longnose gar
Lepisosteus platostomus	Shortnose gar
Lepisosteus spatula	Alligator gar
Lepomis cyanellus	Green sunfish
Lepomis gibbosus	Pumpkin seed
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill or brim
Lepomis marginatus	Dollar sunfish
Lepomis megalotis	Longear sunfish
Lepomis microlophus	Redear sunfish
Lepomis punctatus	Spotted sunfish
Lepophidium graellsi	Blackedge cusk eel
Lepophidium jeannae	Mottled cusk eel
Leptochelia rapax	
Leptogorgia virgulate	Soft coral
Leptosynapta sp.	Holothuroidean

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Lernaeenicus radiatus	
Libinia dubia	Long-beaked spider crab
Libinia emarginata	Spider crab
Ligyda exotica	Sea roach
Ligyda olfersii	Sea roach
Limulus polyphemus	Horseshoe crab
Liriope tetraphylla	
Listriella clymonellae	
Lithophaga aristata	Boring bivalves
Lithophaga bisulcata	Mahogany date mussel, bivalve
Littoridina sp.	Littoridina (undescribed)
Littorina irrorata	Gulf or marsh periwinkle
Littorina ziczac	Zigzag periwinkle
Livoneca ovalis	
Lizzia gracilis	
Lobotes surinamensis	Tripletail
Loligo pealei	
Lolliguncula brevis	
Lophius sp.	Goosefish
Loxothylacus texanus	
Lucania parva	Rainwater killifish
Lucapinella limatula	File fleshy limpet
Lucifer faxoni	
Lucina amiantus	Lovely miniature lucina
Lucina floridana	Florida lucina
Lucina multilineata	Many-lined lucina
Luidia sp.	Starfish
Luidia clathrata	
Lutjanus analis	Mutton snapper
Lutjanus apodus	School master
Lutjanus campechanus	Red snapper
Lutjanus griseus	Gray snapper
Lutjanus jocu	Dog snapper
Lutjanus mahogoni	Mahognny snapper
Lutjanus synagris	Lane snapper
Lyonsia floridana	Florida lyonsia
Lytechinus varigatus	Sea urchin
Macoma brevifrons	Short-snouted macoma
Macoma constricta	Burrowing bivalves
Macoma mitchelli	Bivalves
Macoma tageliformis	Bivalves
Macoma tenta	
Macrobrachium acanthurus	

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Macrobrachium ohione	
Macrocalliata nimbosa	
Macrorhamphosus scolopax	Snipe fish
Mactra fragilis	Fragile Atlantic mactra, bivalve
Makaira nigricans	Blue marlin
Malacocephalus occidentalis	Soft head
Malongena corona	Gastropod
Manta birostris	Giant manta
Marcrocallista nimbosa	Sunray venus
Martesia cuneiformis	Piddock
Martesia striata	Piddock
Megalops atlantica	Tarpon
Meioceras nitidum	Eel grass vitrinellid
Melampus bidentatus	Salt marsh snail
Melanella intermedia	
Mellita fresneli	
Mellita nitida	
Mellita quinquiesperforata	Sand dollar
Melongena corona	Crown conch
Membranipora sp.	Bryozoan
Membranipora membranacea	Sea mat
Membras martinica	Rough silverside
Menidia berryllina	Tidewater silverside
Menippe mercenaria	Stone crab
Menticirrhus americanus	Southern kingfish
Menticirrhus focaliger	Minkfish
Menticirrhus littoralis	Gulf kingfish
Mercenaria campechiensis	Southern quahog
Mercenaria mercenaria	
Merluccius bilinearis	Silver hake
Microciona prolifera	Red sponge
Microdesmus longipinnis	Pink worm fish
Microgobius gulosus	Clown goby
Microgobius thalassinus	Green goby
Micropanope xanthiformis	
Micropogon undulatus	Croaker
Microprotopus raneyi	
Micropterus dolomieui	Small mouth bass
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Micrognathus crinigerus	Fringed pipefish
Micrura leidyi	Leidy's ribbon worm
Mitrella lunata	Lunar columbella, gastropod

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Mnemiopsis mccradyi	Sea walnut
Modiolus demissus	Ribbed mussel
Modiolus modiolus	Snail
Moira atropos	Heart urchin
Mola mola	Ocean sunfish
Molpadia cubana	
Monacanthus ciliatus	Fringed filefish
Monacanthus hispidus	Planehead filefish
Monacanthus tuckeri	Slender filefish
Monoculoides edwardsi	
Monolene antillarum	Antilles flounder
Morone americana	White perch
Morone mississippiensis	Yellow bass
Morone saxatilis	Striped bass
Moxostoma poecilurum	Blacktail redhorse
Muggiaea kochi	
Mugil cephalus	Striped mullet
Mugil curema	White mullet
Mulinia lateralis	Dwarf furf clam, bivalve
Mullys auratus	Red goatfish
Odontaspis taurus	Sand tiger
Murex fulvescens	Spine-ribbed murex, snail
Musculus lateralis	
Mustelus canis	Smooth dogfish
Mya arenaria	Softshell clam
Myctophidae	Lantern fish
Mycotophum affine	Lanternfish
Mycteroperca bonaci	Black grouper
Mycteroperca microlepis	Gag
Myrophus punctatus	Speckled worm eel
Mysella cuneata	Cuneate lepton
Mysella planulata	Atlantic flat lepton
Mysidopsis sp.	Crustaceans
Mysidopsis almyra	
Mysis stenolepis	Mysid
Mystriophis intertinctus	Spotted spoon-nose eel
Mystriophis mordax	Snapper eel
Nannodiella melanitica	
Nanomia bijuga	
Narcine brasiliensis	Lesser electric ray
Nassarius acutus	Pointed basket shell
Nassarius vibex	Common eastern nassa, snail
Natica pusilla	Miniature natica

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Naucrates ductor	Pilot fish
Nausithoe punctata	
Neanthes succinea	Polychaete
Negaprion brevirostris	Lemon shark
Nemopsis bachei	
Neomerinthe hemingwayi	Spinycheek scorpion fish
Neopanope texana	Mud crab
Nephtys sp.	Polychaete
Nereis pelagica	Reddish clamworm
Nerine agilis	Clamworm
Neritina reclivata	Green nerite, snail
Nerocila acuminata	
Noetia ponderosa	Ponderous ark
Nomeus gronovii	Man of war fish
Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
Notropis baileyi	Rough shiner
Notropis emiliae	Pugnose minnow
Notropis petersoni	Coastal shiner
Notropis roseipinnis	Cherry fin shiner
Notropis texanus	Weed shiner
Notropis venustus	Blacktail shiner
Notropis welaka	Blue-nose shiner
Nuculana acuta	Bivalves
Nuculana concentrica	Bivalves
Obelia spp.	
Obelia oxydentata	Double-branching hydroid
Octolasmis mulleri	Goose-neck barnacle
Octopus vulgaris	Octopus
Ocypode albicans	Ghost crab
Ocypode quadrata	Ghost crab
Odontaspis taurus	Sand tiger
Odostomia sp.	
Odostomia impressa	Gastropod
Odostomia seminuda	Half-smooth odostome
Ogcocephalus nasutus	Shortnose batfish
Ogcocephalus parvus	Batfish, roughback
Ogcocephalus vespertilio	Batfish, longnose
Ogilbia sp.	Ogilbia
Ogyrides limicola	
Olencira praegustator	
Oligoplites saurus	Leatherjacket
Oliva sayana	Lettered olive, snail

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Olivella sp.	
Olivella mutica	Little olive
Olivella pusilla	
Onuphis magna	Polychaete
Oostethus lineatus	Opossum pipefish
Ophichthus gomesi	Shrimp eel
Ophidion welshi	Crested tusk-eel
Ophiothrix angulata	Brittle star
Opisthonema oglinum	Atlantic thread herring
Opsanus beta	Oyster fish, gulf toadfish
Orchestia grillus	Beach hoppers
Orchestia platensis	Common sandflea
Orthopristis chrysoptera	Pigfish
Ostrea equestris	Horse oyster
Ovalipes guadalupensis	Portunid crab
Ovalipes ocellatus	Lady crab
Ovalipes quadulpensis	
Owenia fusiformis	
Oxyurostylis smithi	
Pagrus sedecim	
Pagurus annulipes	Hermit crab
Pagurus floridanus	Hermit crab
Pagurus longicarpus	Hermit crab
Pagurus pollicaris	Large hermit crab
Palaemonetes intermedius	
Palaemonetes kadiakensis	
Palaemonetes paludosus	
Palaemonetes pugio	Grass shrimp
Palaemonetes vulgaris	Grass shrimp
Pandora trilineata	Burrowing bivalves
Panopeus sp.	Wharf crab
Panopeus occidentalis	
Papyridea soleniformis	Spiny paper cockle
Paralichthys albigutta	Gulf flounder
Paralichthys lethostigma	Southern flounder
Paralichthys squamilentus	Broad flounder
Paraphyllina sp.	
Parastarte triquetra	3-sided parastarte
Parexocoetus brachypterus	Sailfin flying fish
Pecten papyraceus	
Pelagia noctiluca	
Penaeus aztecus	Brown shrimp, edible shrimp
Penaeus duorarum	Pink shrimp

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Penaeus fluviatilis	White shrimp, common shrimp
Penaeus setiferus	
Pennaria tiarella	Hydroid
Peprilus alepidotus	Harvestfish
Peprilus burti	Gulf butterfish
Periclimenes longicaudatus	
Periploma fragile	Bivalves
Peristedion gracile	Slender searobin
Peristedion miniatum	Common deep-sea gurnard
Persa incolorata	
Persephona crinita	
Persephona punctata	
Petricola pholadiformis	
Petrochirus bahamensis	Large hermit crab
Petrolisthes armatus	Crustaceans
Phacoides radians	Radiate lucina
Phalium granulatum	Scotch bonnet, snail
Phialidium languidum	
Phoronis architecta	Phoronid
Physalia physalis	
Physiculus fulvus	
Pilumnus dasypodus	
Pimephales promelas	Fathead minnow
Pinnixa chacei	Chace's worm crab
Pinnixa chaetopterana	Parchment worm crab
Pinnixa cristata	
Pleuroploca gigantea	Horse conch
Plicatula gibbosa	Kitten's paw
Poecilia latipinna	Sailfin molly
Pogonias cromis	Sea or black drum
Polinices duplicatus	Shark eye sand-color snail
Polycera hummi	
Polydactylus octonemus	Atlantic threadfin
Polydora sp.	Polychaete
Polymesoda carolinensis	Marsh snail
Polymesoda caroliniana	
Polyodon spathula	Paddle fish
Pomacentrus fuscus	Demoiselle
Pomacentrus leucostictus	Beau gregory
Pomacenthus paru	French angle fish
Pomatomus saltatrix	Bluefish
Pomoxis annularis	White carppie
Pomoxis nigromaculatus	Black carppie

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Pontinus longispinis	Longspine scorpionfish
Porcellana sayana	Porcellanid crab
Porcellana sigsbeiana	
Porichthys porosissimus	Atlantic midshipman
Portunus gibbesii	Swimming crab
Portunus sayi	Swimming crab
Portunus spinicarpus	Portunid crab
Portunus spinimanus	Swimming crab
Predilus sp.	Polychaete
Priacanthus arenatus	Bigeye
Prionotus alatus	Winged sea robin
Prionotus carolinus	Northern sea robin
Prionotus evolans	Striped searobin
Prionotus ophyras	Bandtail searobin
Prionotus paralatus	Mexican searobin
Prionotus roseus	Rosy sea robin
Prionotus rubio	Common sea robin
Prionotus salmoicolor	Black wing sea robin
Prionotus scitulus	Slender sea robin
Prionotus stearnsi	Stearn's sea robin
Prionotus tribulus	Bighead searobin
Pristigenys alta	Short bigeye
Pristipomoides aquilonaris	Wenchman
Pristis pectinata	Smalltooth sawfish
Pristis perotteti	Largetooth sawfish
Proboscidactyla ornata	
Prognichthys gibbifrons	Bluntnose flyingfish
Prontogrammus vivarus	Streamer
Psenes cyanophrys	Freckeled driftfish
Rachycentron canadum	Cobia, lemon fish
Rainoides louisianensis	
Raja eglanteria	Clearnose skate
Raja lentiginosa	Freckled skate
Raja texana	Texas clearnose skate
Rangia cuneata	
Remora remora	Remora
Renilla mulleri	Short-stemmed sea pansy
Retusa canaliculata	
Rhinobatus lentiginosus	Guitarfish
Rhinoptera bonasus	Cownose ray
Rhithropanopeus harrisii	
Rhizophysa filiformis	
Rhizoprionodon terraenovae	Atlantic sharpnose shark

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Rhomboplites aurorubens	Vermilion snapper
Rhopalonema velatum	
Rhopilema verilli	
Rissoina chesneli	Chesnel's rissoina
Rissola marginata	Striped cusk eel
Rithrapanopeus spp.	Mud crab
Rocellaria stimpsonii	
Rossia tenera	
Rubellatoma diomedea	
Rypticus saponaceus	Greater soap fish
Sabellaria floridensis	Hartman's sabellaria
Sagitta enflata	
Sagitta hispida	Hispid arrow worm
Sarda sarda	Atlantic bonito
Sardinella anchovia	Spanish sardine
Saurida brasiliensis	Large scale lizzard fish
Saurida normani	Short jaw lizzard fish
Scaphella junonia	Junonia
Sciaenops ocellata	Red drum
Scomber japonicus	Chub mackerel
Scomberomorus cavalla	King mackerel
Scomberomorus maculatus	Spanish mackerel
Scomberomorus regalis	Cero
Scorpaena agassizi	Longfin scorpionfish
Scorpaena brasiliensis	Barbfish
Scorpaena calcarata	Smoothhead scorpionfish
Scorpaena plumieri	West Indian scorpionfish
Scyllaea pelagica	
Scyllarides nodifer	
Seila adamsi	Adams miniature cerith
Selar crumenophthalmus	Bigeye scad
Selene vomer	Lookdown
Semele bellastriata	Cancellate semele
Semele nuculoides	Nuculoid semele
Semele proficua	Burrowing bivalves
Seriola dumerili	Greater amberjack
Seriola fasciata	Lesser amberjack
Seriola rivoliana	Almaco jack
Seriola zonata	Banded rudder fish
Serranellus subligarius	Belted sand fish
Serraniculus pumilio	Least sea bass
Serranus annularis	Orange back bass

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Serranus atrobranchus	Blackear bass
Serranus phoebe	Tattler
Serranus sublingarius	Belted sandfish
Serranus tabacarius	Tobacco fish
Sesarma cinereum	Square-backed fiddler crab
Setarches parmatus	Setarches
Sicyonia brevirostris	Rock shrimp
Sicyonia dorsalis	
Sicyonia laevigata	
Siderastrea siderea	Stony coral
Sinum perspectivum	Prosobranch snail
Solariorbis blakei	
Solariorbis mooreana	Moore's vitrinella
Solenocera vioscai	
Solmundella bitentaculata	
Sphaeroma destructor	
Sphaeroma quadridentatum	
Sphoeroides dorsalis	Marbled puffer
Sphoeroides maculatus	Northern puffer
Sphoeroides nephelus	Florida swellfish
Sphoeroides parvus	Least puffer
Sphoeroides spengleri	Banktail puffer
Sphyraena barracuda	Great barracuda
Sphyraena guachancho	Small barracuda
Sphyraena picudilla	Southern sennet
Sphyrna diplana	Hammerhead shark
Sphyrna lewini	Scalloped hammerhead
Sphyrna mokarran	Great hammerhead
Sphyrna tiburo	Bonnethead
Sphyrna zygaena	Smooth hammerhead
Spisula solidissima	Altantic surf clam
Squalus acanthias	Spiney dogfish
Squatina dumerili	Monkfish
Squilla chydaea	
Squilla empusa	King shrimp, mantis shrimp
Steenstrupia nutans	
Steindachneria argentea	Luminous hake
Stellifer lanceolatus	Star drum
Stenocionpos spinimana	
Stenorynchus seticornis	
Stenotomus caprinus	Longspine porgy
Stomolophus meleagris	Cabbagehead

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Strigilla mirabilis	White strigilla
Strombus alatus	
Strongylura marina	Atlantic needlefish
Strongylura notata	Redfin needlefish
Strongylura timucu	Timucu
Sulceolaria biloba	
Sulceolaria chuni	
Sulceolaria quadrivalis	
Syacium gunteri	Gunter's flounder
Syacium papillosum	Dusky flounder
Symphurus civitatus	Deep-water tongue fish
Symphurus diomenianus	Spotted fin tongue fish
Symphurus plagiusa	Blackcheek tonguefish
Syngnathus floridae	Dusky pipefish
Syngnathus louisianae	Chain pipefish
Syngnathus pelagicus	Sargasum pipefish
Syngnathus scovelli	Gulf pipefish
Syngnathus scovelli	Bull pipefish
Synodus foetens	Inshore lizardfish
Synodus intermedius	Sand diver
Tagelus divisus	Burrowing bivalves
Tagelus plebeius	
Talorchestia longicornis	Long-horned sandflea
Talorchestia mississippiensis	
Tamoya haplonema	
Tapuromysis sp.	Mysid
Tegula fasciata	Snail
Teinostoma biscaynense	
Tellidora cristata	
Tellina alternata	Alternate tellin
Tellina iris	
Tellina lintea	Linen tellin
Tellina texana	
Tellina versicolor	Cousin tellin
Terebra concava	
Terebra dislocata	Dislocated augar shell
Terebra salleana	Salle's augur
Teredo navalis	Ship worm
Tetrapturus albidus	White marlin
Tetrapturus pflueferi	Longbill spear fish
Thais haemastoma	Oyster drill
Thais haemastoma floridana	
Thunnus albacares	Yellow fin tuna

TABLE XIV (Continued)

FISH AND OTHER MACROFAUNA OF THE STUDY AREA

Scientific Name	Common Name
Thunnus atlanticus	Black fin tuna
Thunnus thynnus	Blue fin tuna
Thyone mexicana	
Tozeuma carolinense	
Trachinocephalus myops	Snake fish
Trachinotus carolinus	Common pompano
Trachinotus falcatus	Round pompano
Trachurus lathami	Rough scad
Trachycardium muricatum	Burrowing bivalves
Trachypenaeus spp.	Hardback shrimp
Trachypenaeus similis	
Tricanthodes lineatus	Triaconthodes
Trichiuris lepturus	Atlantic cutlassfish
Trichocorixa verticalis	
Trichopsetta ventralis	Deep-sea flounder
Trinectes maculatus	Hogchoaker
Triphora nigrocincta	Black-circled triphora
Tubularia crocea	Hydroid
Turbonilla sp.	
Turbonilla conradi	
Tylosurus acus	Agujon
Tylosurus crocodilus	Houndfish
Uca minax	Fiddler crab
Uca pugilator	Fiddler crab
Uga pugnax	Fiddler crab
Upogebia affinis	
Urophycis floridanus	Southern Hake, or ling
Urophycis regius	Spotted hake
Velella velella	
Viviparus sp.	Swamp snail
Vogtia glabra	
Vomer setapinnis	Atlantic moonfish
Xanthichthys ringens	Sargassum triggerfish
Xiphias gladius	Swordfish
Xiphopeneus kroyeri	
Yarrella blackfordi	Yarrella
Zalieutes mcgintyi	Tricorn batfish
Zenopsis ocellata	Ocellated dory
Zoobotryon pellucidum	
Zoobotryon verticillatum	

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